PRELIMINARY DRAFT

URBAN AND INDUSTRIAL STORMWATER ASSESSMENT

FOR THE

MONTANA STATEWIDE SECTION 208

WATER QUALITY MANAGEMENT PLANNING AREA

by:

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INTRODUCTION

STUDY AUTHORIZATION

The stormwater assessment presented herein has been conducted by the Water Quality Bureau as part of Montana's Statewide 208 project. The project was financed through a Section 208 Water Quality Management Planning Grant from the U.S. Environmental Protection Agency.

PURPOSE AND SCOPE

The purpose of the urban stormwater inventory was to assess the existing stormwater problems and facilities and their related stream impacts within the non-designated Montana Statewide 208 Area. The inventory identifies present and potential water quality problems and possible solutions.

The scope of this project includes in-depth considerations for all towns with a 3,000 population or more, cursory mapping and considerations for all communities of 100 population or more, and evaluation of runoff effects from selected industries with large land areas. A stormwater model was utilized for pollutant loads. A suspended solids-turbidity-flow relationship was used to assess stream impact.

PROBLEM DEFINITION

The process of urbanization radically changes stormwater runoff flow characteristics. Velocity and quantity of runoff is greatly increased. As a result, large quantities of various pollutants including total suspended solids, organics, nitrogen and phosphorus are washed into stormwater channels. The receiving stream can be subjected to shock levels of polluted water during larger precipitation events. Actual water quality impacts will vary with stream size and urban drainage area.

The problem is to determine whether present or potential degradation exists, and what steps are necessary to abate this water quality problem.

ASSESSMENT APPROACH

To more accurately assess the extent of urban stormwater pollution in Montana, a review of the published literature was undertaken. An overview of national stormwater problem management was necessary to tailor the assessment to Montana's present population characteristics.

Most stormwater research has been done on populous areas. Since Montana has only two cities with more than 60,000 population, the definition of "urbanized area" as used in the present assessment is modified to include some of the smaller communities.

The methods to be used to evaluate present and future stormwater runoff problems in specific cities were dictated by the literature review. A stormwater model was chosen to generate pollutant loads and sufficient field data were then gathered.

A procedure to assess stormwater pollutant impacts on water courses was developed and applied to each community within the study scope. Results were reviewed and recommendations for further study or problem solution were made.

LITERATURE REVIEW

STORMWATER HYDROLOGY

The purpose of this section is to review stormwater literature and briefly discuss past research which has comparative application to the Statewide 208 stormwater runoff assessment. The review will demonstrate that stormwater is deleterious to stream quality based on previous research. Discussion will include combined and separate stormsewers, stormwater contaminants, control measures, and other aspects such as Montana-oriented data.

For years, stormwater quality was ignored, apparently because domestic sewage was receiving less than desirable treatment. Now that domestic sewage has approached the secondary level of treatment, attention is turning to non-point sources of pollution such as stormwaters, irrigation returns, and agricultural surface runoff.

An early report by McKee (1947) discusses combined sewers. He developed an analytical method for determining a relationship between interceptor sewer capacity, quantity of sewage lost during overflows, and the duration and frequency of overflows. Overflows are a common problem in combined sewers. Combined sewers carry domestic sewage during dry periods, and both domestic sewage and stormwater during runoff periods. Some storms are intense enough to cause an overflow directly to a lake or stream.

Many combined sewers were once designed to have an overflow during any rain event in order to clean the sewers of solids deposited during dry weather flow. These solids are one of the biggest quality problems associated with combined sewer overflows.

The solids undergo anaerobic digestion in the sewer line so that when flushing occurs, the quality of the overflow is extremely poor.

McKee studied hourly precipitation data for Boston from 1934 through 1945. He observed that 0.03 inches/hour were required before any street runoff occurred. His general analytical method is excellent for design of stormsewers and is used with modification today.

Later (July 1961), Moorehead studied combined sewer overflows in Washington, D.C. He presented a description of the combined sewer system for the city and the history and future of the Washington, D.C. system. This paper is a very good indicator of public and professional sentiment in the early 1960's regarding stormwater and its pollution potential.

Concurrent with Moorehead's report, Johnson reported on the Washington, D.C. combined sewer system. His paper is more valuable than Moorehead's because it presents stormwater data and graphs as well as a basin lag time calculation.

Lag time is important in any stormsewer analysis. It is evident that from the time rainfall begins until a peak discharge flow occurs, there exists a time lag or a basin lag time. Johnson's paper is one of the first to actually calculate this lag time for a storm drain system. Earlier papers have dealt with lag time, but purely with respect to flood control and determination of the day peak floods could be expected.

Taylor and Schwartz, in April 1952, presented a nomograph whereby one can determine lag time and peak flow as long as length of the longest watercourse in a basin, distance from the point in

question to the basin's centroid, main channel slope, and drainage area are known. This particular method is applicable to basin wide storms only.

Benjes, et al. (1961) discussed Kansas City stormsewers. They found a 0.04 inches/hour storm was required before any runoff occurred. Also, they reported that a 0.12 inches/hour storm is required to begin runoff from pervious areas. They presented a graph of rainfall and runoff intensity versus percent of total time. This graph provides a visual assessment of a basin's runoff quantity problem. One of the more interesting aspects of this paper is that it ignored the three snowy winter months due to the claim that snowmelt analysis is a bit too complicated.

In February 1963, Palmer studied the combined sewer systems in Detroit. He also found that a storm inventory of 0.04 inches/hour was required for runoff from impervious sources. Palmer's paper also discussed the feasibility of separate or combined sewer systems; he supported combined sewers.

Weibel, et al. (July 1964) researched urban land runoff on a 27 acre plot in Cincinnati. The plot was 37% impervious and had a 3% maximum slope. The data showed that the normal annual runoff contained essentially the same pollutant load as that of raw sewage for the area. This particular paper was important because it was one of the first papers that considered the importance of the relationship between an antecedent dry period and the quality of runoff. This paper documents that the longer the antecedent dry period, the poorer the quality of stormwater runoff.

Burm, et al. studied the Detroit and Ann Arbor stormsewers from April to November 1965. They found that BOD discharged from separate

stormsewers was generally 1/5 of that experienced at combined sewer overflows. They also found that absolute values for all solids parameters were much higher in a separate stormsewer than in a combined. They also noted the significance of a first flush phenomenon was non-existent in relation to suspended solids concentrations for combined sewer discharges. Of the nutrient parameters tested, they found that phosphate values were higher and nitrate concentrations lower in combined sewers. They found that soluble phosphate concentrations in Ann Arbor's stormwater was 1/10 of the soluble phosphate concentrations in combined sewers for phenols, organic nitrogen, and total phosphates. They found higher concentrations in separate sewer systems for suspended solids, volatile suspended solids, settleable solids, and nitrates. Finally, it was estimated that 15% of the BOD load was lost to the Detroit River during summer, 1976 overflows.

In 1968, Geldreich, Best, Kenner, and Van Donsel reported on the bacteriological aspects of stormwater pollution in Cincinnati. They presented data that showed highest urban fecal total and fecal streptococcus concentrations occur in summer and autumn; highest rural area concentrations occurred in winter.

Metcalf and Eddy (1971) studied Oakland and Berkeley stormsewers. They observed the first flush phenomenon also. In addition, they found that the general BOD of the stormwater overflow was 200 mg/L. Oil and grease averaged approximately 50 mg/L and coliform bacteria was in the 10^8 per 100 ml range. Ratios were computed for peak wet weather flows to average dry weather flows and ranged from 2.1 to 9.1. They found that bypasses of the sewage plant occurred 12 times per year and totalled 1.040×10^9 gallons or

4.3% of the total annual rainfall.

In July 1971, Metcalf and Eddy, in cooperation with the University of Florida and the Water Resources Engineers Incorporated, formulated a stormwater management model capable of representing urban stormwater runoff and combined sewer overflow phenomena. The model accepts any rainfall hydrograph or multiple hydrograph and produces a runoff hydrograph for each model watershed. The model produces a continuous runoff-quality graph called a pollutograph. Hydrographs and pollutographs can be computed for dry weather flows with daily and hourly variations including infiltration. The model can also analyze various methods of treatment and their effectiveness. This model is written in Fortran and has successfully been tested by independent computer systems.

DeFillippi and Shih (1971) wrote about the characteristics of separate storm and combined sewer flows. Their paper shows that in the District of Columbia storm systems, the average BOD in combined sewers is generally higher than in closed stormsewers; however, the ratio of BOD in combined and separate systems is not as great as in other studies, particularly Burm's. As with Burm's report, higher solids values were recorded in straight stormwater flows than in combined flows. They experienced the same phosphate phenomenon as did Burm; however, they were unable to compare COD measurements at this time.

Contrary to the Detroit study (Burm, et al., 1965), DeFillippi and Shih found that volatile suspended solids were higher in combined sewers than in stormsewers. The differences were due to locations and geomorphological characteristics. Wastewater characteristics of any combined sewer discharge did not seem to be

influenced by rainfall for short duration storms. The first flush effect was evident in all cases. Concentrations of waste constituents increased in proportion to the discharge rate during the initial first flush period. For short intense storms, the concentration of pollutants was very high and remained so during the discharge period. The cleansing effect was exhibited in long storms only after the first flush period was finished. They also noted that quantity of waste materials carried by the first flush was proportional to antecedent dry period length. It was found that bacteriological counts were much greater in the initial flush and that fecal coliforms in stormsewer discharges were approximately 1/8 that in combined sewer discharges. Also, it was evident that storm runoff flow patterns for combined and separate systems were impulse, nonsteady state patterns. In view of the ratio of BOD to COD, they concluded that a depression of biological oxidation in the sewer is to be expected. And finally, they concluded segregation of domestic sewers from stormsewers should be reconsidered because significant pollution loads are found in separate stormsewers.

Lager, Shubinski, and Russell (1971) wrote about the development of a simulation model for stormwater management. They analyzed the Baker Street combined sewer in San Francisco to verify and refine their model. The comprehensive mathematical model accurately represents the quantity and quality of stormwater runoff overflows. The model data included topography, land use, population, pipe sizes and slopes, flow diversions, regulators, inline structures, street sweeping and washing frequency, receiving water flows, dry weather flow characteristics and variations, rainfall, and hyeto-

graphs. Graphs presented document the model's accuracy.

In March 1973, Chen and Saxton wrote about combined wastewater overflows and improved McKee's methods discussed earlier. This team used data from Spokane, but did not study snowmelt. They only considered that runoff occurred when precipitation was 0.03 inches per hour or greater. The paper presented a method which related the simple synthetic hydrograph to runoff, annual dry weather flow, and tributary service area of a combined sewer system. Their method allowed analysis of future developments.

In February 1974, McElroy and Bell wrote about stormwater runoff from an area which was 55% impervious and 45% roofs. Their tests showed BOD was five times higher and peak TSS was two to ten times greater in urban than in rural areas. First flush phenomenon was not as evident in the rural basin as in urban areas. In addition, they found that the pollutograph was more affected by flow than by pollutant concentration.

In March of 1974, Sartor, et al. wrote about pollution aspects of street surface contaminants. They showed that much of the pollution occurring from street washing is associated with extremely fine particles of less than 43 microns, since most of these particles are not affected by conventional brush type street sweeping. Also, catch basins do a very poor job of removing these small particles. The paper concludes that better street sweeping methods and vacuum sweeping could be more effective in reducing pollutional loads from stormwater runoff.

In April 1974, Graham, Costello, and Mallon developed formulas for determining degree of imperviousness for a basin based on curb length. The degree of imperviousness is valuable in calculating

runoff quantity with the formula discussed by Linsley, Kohler, and Paulhus in 1958.

In May 1974, Metcalf and Eddy prepared a national urban stormwater management technology assessment. The voluminous paper discusses the general condition of stormwater at that time and concluded that every metropolitan area in the U.S. has a stormwater problem. The paper concluded problems are best quantified when discharges are compared on a mass loading basis instead of on an hour basis. They also noted in many cases, aesthetic problems are the primary stormwater pollution concern.

In May 1974, Klushner and Lee discussed nutrient loading from the Manitou Way stormsewer to Lake Wingra at Madison, Wisconsin. They found that: percent runoff equals percent street pavement in the basin; nutrients and TSS both exhibited a first flush phenomenon; phosphorus had a high spring and fall concentration; nitrogen had a high spring and fall concentration; nitrogen had a high spring concentration; while nitrogen came mostly from rain, phosphorus came mostly from litter and falling leaves; 80% of the phosphorus and 40% of the nitrogen in Lake Wingra came from stormwater; and the highest TSS observed occurred on March 14, 1971 when "an intense brief shower flushed the basin of the last remnants of winter snow".

In January 1976, the influence of land use on streams' pollutant levels was discussed by Omelnik. This paper concludes that streams draining agricultural lands have a higher nutrient concentration than those draining forested watersheds. Phosphorus concentrations were found to be nearly 10 times as great in streams draining agriculture land as in forested stream drainages and mean total nitrogen was about 5 times as great. Interestingly enough, it was found that

differences in nutrient loads in streams associated with different land use categories were not nearly as pronounced as the differences in nutrient concentrations. It was noted, for example, that the mean total phosphorus export from agricultural lands was 3.7 times that from forested lands and a mean total of nitrogen export was 2.2 times greater. One further point of interest was the conclusion that no clearly significant relationships were found between geology and stream nutrients.

In February of 1976, Cowan and others studied nitrogen availability in urban runoff at Madison, Wisconsin. They showed that 70% of the total nitrogen runoff in a certain lake was in the algal available form. Their important conclusion was that any laboratory analysis on stormwater samples should be for total nitrogen instead of just for available nitrogen. Cowan followed this study with a study in association with Lee in March 1976 and discussed phosphorus availability in particulate materials transported by urban runoff. This study concluded that particulate phosphorus from different land uses was similar, indicating that the major source of phosphorus in runoff is dustfall and not necessarily land use. They also derived a formula to determine total available phosphorus (soluble phosphorus plus 3/10 the particulate phosphorus) in runoff.

Heaney, Huber, and Nix in October 1976, presented one of the most basic stormwater management models ever written. It is a simple analysis of stormwater problems and is used in the current report (see page 23). The model is representative of all average U.S. conditions and involves the use of precipitation, land use, population, and street sweeping characteristics.

In November 1976, Dendy and Bolton presented a paper on sediment

yield and runoff drainage for area relationships in the U.S. This paper derives sediment yield formulas for both annual runoff of less than and greater than two inches. The area with less than 2 inches runoff closely approximates that which one would expect in a first flush condition.

In August 1976, Lager, Didricksson, and Otte developed a simplified stormwater management model. The report is important for the graph developed to determine the imperviousness of an area from knowledge of population density.

Concurrently, Horton (1976) studied street sweeping and street dirt. He found the composition of street washing pollutants to be toxics, solids, and oxygen consuming materials. The report concludes that vacuum sweeping will protect a stream from pollution much better than mechanical methods. This confirms with the earlier report of Sartor et al. (page 10).

STORMWATER QUALITY

Palmer (1950) did one of the first investigations of stormwater quality. Catch basins in Detroit were sampled for separate stormsewer water quality. Coliforms ranged from 25,000 to 930,000 per 100 milliliters, total solids ranged from 310 mg/L to 914 mg/L, volatile solids ranged from 136 mg/L to 414 mg/L, and BOD-5 ranged from 96 mg/L to 234 mg/L.

He also reported values for combined sewer overflows, documented quality changes to be expected for different rates of overflow, and found that when stormwater flow is 2 to 2½ times the dry weather flow, the quality can be expected to be:

Coliforms per 100 ml	Total Suspended Solids (mg/L)	Volatile Suspended Solids (mg/L)	BOD-5 (mg/L)
4,300,000	250	100	50

Riis-Carstenson (1955) reported on the stormsewers in Buffalo. His readings for the combined sewers showed increases in solids during a rain storm, but decreases in BOD in the same storm.

Palmer wrote about the Detroit stormsewers again in 1963. The small amount of data that he presented in this report show :

Coliform/100 ml	Mean Suspended Solids (mg/L)	Volatile Solids (mg/L)
2,300-430,000	100-213	38-121

Weibel, Anderson, and Woodward wrote about the Cincinnati storm drains in July 1964. Their data show :

BOD-5 (mg/L)	Turbidity (JTU)	pH (S.U.)	Color (S.U.)	Alkalinity	Chloride	Total Suspended Solids (mg/L)
2-84	30-1,000	5.3	380	Very Low	Very Low	1,200

NH_3 (mg/L)	Volatile Solids (mg/L)
1.9	290

In 1968, Burm, Krawczyk, and Harlow discussed the Detroit and Ann Arbor stormsewers and compared analyses from some of these sewers. The Ann Arbor separate stormsewer data showed:

BOD-5 (mg/L)	TSS (mg/L)	Volatile Suspended Solids (mg/L)	Phenol (mg/L)	Total Settleable Solids (mg/L)
16-62	11,900	570	70	11,100

Also in 1968, Evans, Geldreich, Weibel, and Robeck again discussed the Cincinnati storm drains. They recorded stormwater pollutant concentrations of:

Total Coliforms per 100 ml	Fecal Coliforms per 100 ml	Fecal Strep per 100 ml
23,900-45,000,000	1,050-1,210,000	5,000-290,000

Interestingly, the seasonal data showed highest fecal, total, and fecal strep concentrations occurred in Cincinnati in the summer and fall, but in rural areas in winter.

In October 1971, DeFillippi and Shih discussed the Washington, D.C. stormsewers, one of which was a separate stormsewer. They recorded concentration ranges of:

Total Coliforms per 100 ml	Total Solids (mg/L)	BOD-5 (mg/L)	TSS (mg/L)
120,000-3,200,000	338-14,600	3-660	130-11,280

COD (mg/L)	Settleable Solids (mg/L)	Fecal Coliform per 100 ml	Fecal Strep per 100 ml
29-1,514	7,640	1,300,000	60,000

In 1974, Shultz and Comerton discussed the airport at Dorval, Canada. This airport serves the Montreal area. Their report discusses aircraft de-icers, the effect on oxygen requirements in a nearby stream, and documents BOD as high as 4,780 mg/L in the airport runoff.

In 1974, Kluesner and Lee studied the stormwaters in Madison, Wisconsin; particularly, with regard to nutrients discharging into area lakes. The recorded concentrations of:

TSS (mg/L)	NO_3 as N (mg/L)	NH_3 as N (mg/L)
777	1.64	0.47

Organic N (mg/L)	Total Phosphorus
14	1.52

Cowan and Lee again discussed the Madison, Wisconsin stormsewers

in March 1976. Their discussion concerned phosphorus content of Lake Wingra. They recorded concentrations of particulate phosphorus as high as 2.85 mg/L.

Other available reports point to equally high ranges of pollutant concentrations. These and other data are presented in the Appendix A.

STORMWATER QUALITY CONTROL

To control stormwater effects, one must control the water source or water discharge at the point of intersection with a stream or lake. Source control would mean reducing the quantity of flow or changing runoff quality. Control of discharge would involve diverting flow from the stream or treatment of the flow prior to discharge to the stream. These alternatives have been discussed in past literature.

Waller and Colter in 1974 presented a mass balance diagram for stormwater flows (Figure 1). This figure is a representation of the sources and destinations of stormwater flows and makes it very easy to see what would be required to improve the quality or to decrease the pollutional effects of stormwater discharges. For instance, the figure shows that stormwater pollution effects can be reduced by decreasing the amount of dustfall or air pollution particulates in the basin.

Many early papers on storm sewage problems were not geared towards solving pollution requirements. They were merely geared toward designing a sewer to bypass excessive flows to an outfall so overflows or overloading of sewage treatment plants did not occur. This naturally meant that any time a storm occurred, combined sewer overflows discharged into streams. Many early papers which did discuss pollution of a combined sewer overflow took the shaky position of trying to explain the combined sewer overflows were really not too bad; that, in fact, stormwaters were beneficial as a diluting factor. BOD's have been shown to decrease in combined sewer overflows as compared to regular dry weather flows; however, characteristics of

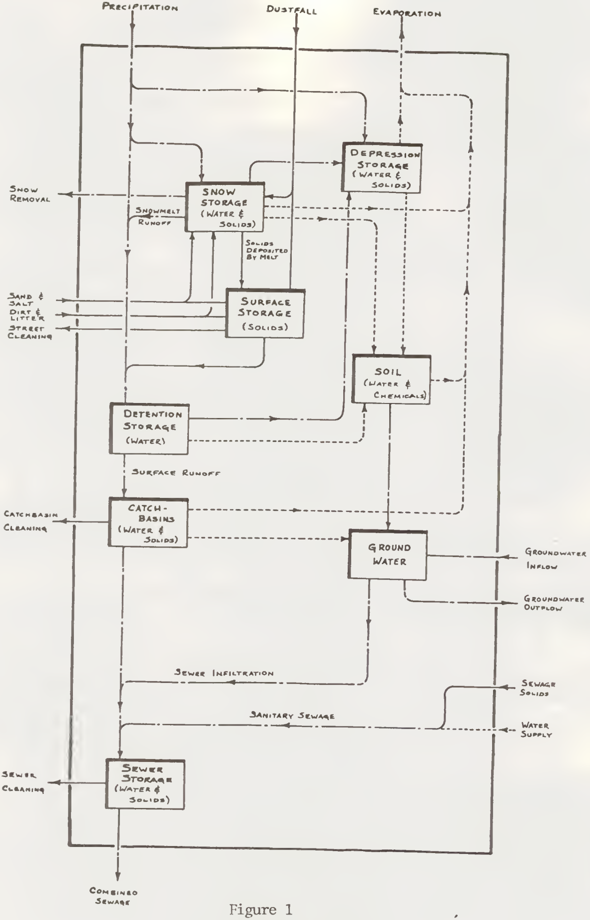

Figure 1

MASS BALANCE DIAGRAM

some parameters, such as solids, are worse in combined sewer overflows than in raw sewage.

One of the first papers to actually discuss stormwater treatment was presented by Evans, Geldreich, Weibel, and Robeck in 1968. These people investigated the feasibility of settling and chlorination to treat stormwaters. They found that less than one hour of plain settling was not helpful in removing COD, BOD-5, Nitrogen, and Phosphate. They also found that 2 to 6 mg/L of chlorine applied for 20 minutes were necessary to cause a 99.99% kill of total fecal coliforms, total coliforms, and fecal strep. They observed an after-growth of total coliforms in the 24 to 72 hour period after disinfection. An after-growth of fecal coliforms and fecal strep was not noticed.

Some common abatement methods now practiced for stormwater control along with affected contaminants are discussed below. Relationships affected by these methods are illustrated in Figure 1.

Snow contributes to stormwater flow and contamination. Snow removal will limit the amount of water available for runoff and also contaminants entrained in the snow mass. These contaminants include sand and salt from road treatment and atmospheric particulates from air scrubbing actions. Snow removal disposal sites should be carefully chosen with regard to slope and proximity to a stream or lake.

Decreasing amounts of dirt and litter deposited on the ground along with decreased use of salt and sand for ice control will improve stormwater quality.

Various cleaning programs are especially valuable in controlling stormwater quality. A municipal program of stormwater control should include street sweeping and catch basin cleanout. In addition, elim-

ination of all sanitary connections to stormsewers should be undertaken.

Street sweeping, as mentioned earlier, is an effective tool for removing stormwater pollutants. The kind of sweeping depends on the extent of the problem, but vacuum sweeping is more efficient than broom sweeping. Frequency depends on periods between rainfall and municipal financial considerations. A sweeping frequency of at least once per month is desirable, although any sweeping program is much better than none at all.

Catch basin cleaning will eliminate leaves and other trash washed from the street. Periodic cleaning will also prevent washing over of previously settled particulates into the stormsewer.

Some methods of stormwater pollution reduction lend themselves to residential and municipal planning. These methods involve integrated structural controls, such as increase of detention time of water storage. This would be some sort of holding pond to allow settling time for solids. A second method involves increasing depression storage. Depression storage is provided by areas which hold small quantities of runoff so that it is slowly released by percolation, reaching the water course after the initial runoff. Another method involves enhancing evaporation potential of some areas.

Some methods of stormwater pollution reduction can easily be added to newly developing sites through use of landscaping techniques. For instance, water drainage could be designed to flow across open, vegetated fields instead of in a channel. In addition, swales with dense vegetation might transport water adequately with much less erosion and more settling. Helena has some drainages that flow

through areas of cattail growth, which provide excellent settling and some removal of nutrients and BOD-5.

TOWNS AND PROCEDURES

INTRODUCTION

This project was limited to cities (listed below) having a population of 3,000 persons or more. Towns with a population of less than 3,000 were covered in a cursory manner. All cities not discussed in this report are those located in the Designated 208 Study Areas.

City	Population (1970)
Anaconda	9,771
Butte	23,368
Cut Bank	4,004
Deer Lodge	4,306
Dillon	4,548
Glasgow	4,700
Glendive	6,305
Great Falls	60,091
Havre	10,558
Helena	22,730
Lewistown	6,437
Libby	3,286
Livingston	6,883
Missoula	29,497
Shelby	3,111
Sidney	4,543

The review of smaller communities with a population of 100 or more is being compiled as inspections are completed by Water Quality Bureau personnel during routine field work.

In addition to communities, a few industries with large land areas were considered for stormwater impact. These were:

Anaconda Company - Anaconda
Anaconda Company - Great Falls
Hoerner-Waldorf - Missoula
Holly Sugar - Sidney
Malstrom Air Force Base - Great Falls

The approach used in this stormwater inventory was budgetarily restricted to desktop calculations. Accurate data derived from specific, onsite measurements of flow and pollutant concentration

require much time spent on site during different rainfall events. The unpredictable and sporadic nature of precipitation, along with inconsistent rainfall intensities make on-the-spot measurement of sixteen towns an exceedingly complicated logistical problem.

Thus, a model was needed which would allow incorporation of parameters easily measured at any time, or readily available from existing literature. As mentioned earlier, various stormwater models have been developed for use in projecting runoff and pollutant estimates. The model used in this study is "Stormwater Management Model Preliminary Screening Procedures", EPA-600/2-76-275, by Heaney, Huber and Nix. Data needed to use this model include land use, type of stormsewer system (combined or separate), precipitation, population density, and street sweeping frequency.

To obtain these data, a questionnaire (Appendix B) was sent to the 16 communities. Response to these questionnaires was good, but with the exception of Glendive, Libby, and Shelby, inadequate. Questionnaires were subsequently completed by members of the Water Quality Bureau staff during visits to all cities involved except Glendive and Shelby.

Some of the data used directly in the model included mean annual precipitation, drainage delineations, and percent land use. Other data were used to generate data for the model. Specifically, land usages were used to generate population density function, and street sweeping frequencies were used to determine street sweeping effectiveness factors.

Other data were modified to fit the intentions of the model. Specifically, street sweeping is a common, warm weather practice in Montana, but ceases in colder months. Reported frequencies of

"Once per Week" were therefore, changed to reflect actual annual effectiveness before being used in the model. Also modified was the low stream flow values for Glendive and Sidney. Using the minimum or established 7-day, 10-year low flow would not show the effects of new dam construction upriver; therefore, instantaneous low flows were used.

Population density (PD_d) was calculated by dividing total population by total residential areas (includes residential areas not in major drainages outlined on Figures 2 through 17).

Population density is one of the variable figures used in these annual load calculations. The allocation of residential areas, while based on actual field data, is nonetheless quite subjective and variable. Great effort was made in this study to get actual land use percentages. The population used is the 1970 census rather than projected population. The difference due to extra growth for Montana is assumed to be insignificant since a large portion of new development is occurring outside most cities' limits.

The population density function adjusts pollutant estimates to allow for density variations within urban areas. The function assumes constant numbers for commercial, industrial, and open areas. Population Function:

$$\text{Residential } f_2(PD_d) = 0.142 + 0.218(PD_d^{0.54})$$

$$\text{Commercial \& Industrial } f_2(PD_d) = 1.0$$

$$\text{Open } f_2(PD_d) = 0.142$$

The street sweeping effectiveness factor accounts for decreased deposits of pollutants due to street sweeping. It is based on studies done in Des Moines, Iowa which show that a steady state condition was reached in twenty days after which pollutant loading on streets was not increased. The street sweeping effectiveness factor utilized a fraction

as follows:

$\gamma = N_s/20$ if $0 \leq N_s \leq 20$ days or

1.0 if $N_s > 20$ days;

N_s is the street sweeping frequency in days.

This function should probably be modified for drier climates such as Montana, where precipitation events are much further apart. Since rainfall in Des Moines, Iowa occurs more frequently than Montana, there is a shorter interval between events and, hence, a shorter effective interval available for street sweeping. For instance, if rainfall is assumed to occur at least once every 20 days, then sweeping would have to occur within that period to prevent washing of contaminants to the stormsewer.

In Montana where a rainfall event (of sufficient size) may occur after a 30-day interval or more, the sweeping interval could be longer with the same effectiveness in preventing contaminated runoff. The street sweeping factor in this model for pollutant loads is directly proportional to the resulting pollutant load. If a factor of X/30 is assumed for the Montana area, then a 30-day or larger interval of sweeping would put the total accumulated load in the stormwater discharge, but an increase in sweeping to once every two weeks would decrease the calculated load by 50%. Sweeping frequencies of as little as once every three months probably significantly decreases pollutant deposits on Montana streets.

Each community was divided into drainage areas determined by destination of the runoff. If the drainage area was sufficiently large, land use percentages were obtained. This permitted calculations for separate drainage areas as shown below. The relationship used is as follows (Heaney, et al., 1976):

$$M = \alpha(i,j) \times P \times f_2(PD_d) \times \gamma \text{ lbs/acre-year}$$

M = Pounds of pollutant per acre-year

$\alpha(i,j)$ = Pollutant Load Factor for type of sewer and type of pollutant

P = Precipitation (inches per year)

PD_d = Population Density function (Constant values for non-residential areas)

γ = Street Sweeping Effectiveness Factor

$\alpha(i,j)$ is obtained from a prepared table provided with the model.

$\alpha(i,j)$ is based on values obtained from actual measurement of urban runoff. It contains overall averages which can be applied to most cities with a fair level of confidence.

Annual average precipitation data were gathered from the USGS publication, "Climates of the States". If a specific value for a community was lacking, interpolation between known data points was used.

Pollutant loadings were calculated for total suspended solids (TSS), 5-day Biochemical Oxygen Demand (BOD-5), Phosphorus (PO_4), and Nitrogen (N). Total load was determined by multiplying loading rate by drainage area.

This model does not require the input or determination of runoff quantities. However, average annual total runoff was calculated, for information and comparative purposes, using a method from the model by Heaney, Huber and Nix. The relation used is:

$$\text{Annual Runoff} = (.15 + .75\ I/100)P - 5.234(DS)^{.5957}$$

Where:

I = Imperviousness (%) = $9.6\ PD_d^{(.573\ -\ .391\ \mathrm{Log}_{10} PD_d)}$

DS = Depression Storage = $.25 - .1875(I/100)$ (inches)

P = Annual Precipitation (inches)

PD_d = Population Density as described earlier

STREAM IMPACT ANALYSES

To assess the effect of these annual pollutant loads on stream quality, a comparative relationship has to be utilized. Of the calculated pollutants, only suspended solids are readily applicable to Montana Water Quality Standards which specify a limitation on turbidity increases for a particular stream reach. Specific numerical limitations of BOD-5, N, or PO_4 do not exist; therefore, turbidity violations due to storm water discharges will be used to indicate stream pollution for the 16 cities mentioned previously.

Though no statewide relationship between suspended solids increase and turbidity increase exists, such relationships can be developed for specific rivers. However, the reliability of such a relation must be questioned in light of its application. In this paper, the relationship is used in a relative manner to point out potential problems which are then further investigated. The turbidity versus TSS relationship was developed from data on the Middle Yellowstone River (Appendix C). The lower turbidity range formula was used:

$$Y = 2.73(X) + 2.8$$

$$Y = \text{TSS (mg/L)}$$

$$X = \text{Turbidity (J.T.U.)}$$

The maximum permissable turbidity increase was used to obtain a maximum TSS increase allowable.

The following method was used to calculate total number of hours needed to dilute stormwater and still not exceed turbidity limits.

1) Find total annual pounds TSS discharged to stream from desktop inventory (pounds/year).

2) Obtain low flow in cfs (7-day, 10-year, if possible). Sources used in this paper are listed in Appendix D.

3) Use the relation for turbidity and TSS from the Yellowstone River at Billings:

$$TSS = 2.73\ J.T.U. + 2.8$$

Assume a turbidity increase limitation of 10 J.T.U., then:

$$TSS = 2.73(10) + 2.8$$

$$TSS = 30.1\ mg/L \text{ increase allowed.}$$

If the turbidity increase is 5 J.T.U., then:

$$TSS = 16.45\ mg/L \text{ increase allowed.}$$

4) To find Minimum Dilution Time of discharge for maximum turbidity increase:

$$\text{Time (hours)} = {}^{*}16{,}018 \left(\frac{\text{pounds/year}}{(3{,}600)(\text{flow in cfs})(TSS)}\right)$$

* The conversion from lbs/ft^3 to mg/L

This "Minimum Dilution Time" can be compared to total runoff hours. The estimated available total runoff hours was calculated from an average year's data (1951) for Lewistown, which has an annual precipitation of approximately 13.00 inches. The figure of 500 hours was used as a basis of comparison for all sixteen communities which are similar in drainage, population, and rainfall.

The resulting Minimum Dilution Time is compared to the average annual runoff time of 500 hours to determine if enough runoff time exists for sufficient dilution. If the Minimum Time is greater than 500 hours, turbidity violations of water quality standards can be expected. If these excess turbidities are sufficient, damage to water quality and stream biota is sustained. Further biological field investigations would be necessary to ascertain extent of damage.

LARGE TOWNS

ANACONDA

Anaconda is an industrial town located on Warm Springs Creek in Deer Lodge County. The drainage area totals about 832 acres with an annual precipitation of 13.22 inches. This community is divided into five drainages (Figure 2) discharging in two directions. One of these directions is directly to the municipal sewer system. This wastewater is then discharged to the Anaconda Copper Company's treatment lagoons. After lagoon treatment, the wastewater discharges to the Clark Fork River. The other direction of runoff is to Warm Springs Creek.

Anaconda uses stormsewers and curbed streets for stormwater control. There is a street sweeping program for the 100 miles of pavement, averaging twice monthly. Snow is collected as needed and piled at three different locations (Figure 2), two of which are quite close to Warm Springs Creek. Sand is used to control ice.

Pollutant loads, as calculated for the two discharges are presented in Table 1. The land use for individual drainages is also presented in Table 1.

The annual runoff was calculated using total acreage to give:

$$AR = 6.48 - 1.79 = 4.69 \text{ inches or } 3{,}902 \text{ acre-feet.}$$

The Minimum Dilution Time was calculated for Warm Spring Creek for a low flow of 20 cfs and a turbidity increase of 10 J.T.U.:

$$\text{Time (hours)} = 16{,}018 \left(\frac{112{,}904}{3{,}600(20)y}\right)$$

$$y = 30.1 \text{ for } 10 \text{ J.T.U.}$$

$$= 834 \text{ hours or } 35 \text{ days.}$$

Since this is more than the estimated average annual runoff time of 500 hours, Warm Springs Creek is possibly suffering from excessive

TABLE 1

ANACONDA

Drainages 1, 3, 4, and 5 discharge to Warm Springs Creek.

Drainage 2 discharges to the municipal sewer system.

Basin	Area (ac)	Residential	Land Use % Commercial	Industrial	Open
1	473	65.4	15.2	0.7	18.7
2	126	52.5	20.0	5.0	22.5
3	122	80.0	2.2	0	17.8
4	68	34.9	9.3	20.9	34.9
5	43	11.1	3.7	11.1	74.1
Total of 1,2,3,4, & 5	706	62	12	3	23

Pollutant Loads (lb/year)

Discharge	TSS	BOD_5	PO_4	N
Warm Springs Creek	112,904	7,020	260	1,022
Anaconda Lagoon	20,463	1,517	50	198

stormwater contaminants. The pollution is important since Warm Springs Creek flows through a municipal park close to town where the effect of stream degradation could be highly visible. The esthetics of this creek are particularly important since Warm Springs Creek experiences frequent public use, both contact and non-contact water sports, in the vicinity of the park area.

It is recommended a biological assessment of Warm Springs Creek be performed to determine the effect of the stormwater discharges to this stream.

BUTTE

Butte is located on the confluence of Blacktail Creek and Silver Bow Creek in Silver Bow County. There are 18 organized drainages (Figure 3), 6 of which discharge to Blacktail Creek. Stormwater is controlled by use of stormsewers in conjunction with curb and gutter in most areas. The 79 miles of paved streets are cleaned twice yearly. In addition, the central business district and other commercial areas are cleaned weekly. Vacuum, broom, and flushing are utilized in the cleaning program. The area not contained in the organized drainages is labelled drainage 19 (Table 2) with a total area of 991 acres.

There is a snow removal program throughout the city limits. Snow is piled in the northwest section of town, east of Excelsior Avenue, west of Montana College of Mineral Sciences and Technology, and between Irvine, Utah, Cobban, and Kaw Avenues. This last location is at the confluence of Blacktail Creek and Silver Bow Creek.

Salt is used alone as well as in conjunction with sand on street surfaces in the amount of 175-225 tons/year. Sand is also used alone in the quantity of 350-550 tons/year.

The basic computations were executed for both the Silver Bow and Blacktail Creek drainages. Stream impact was assessed only for Blacktail Creek since the Silver Bow Creek classification is so low no real limits are placed on its quality. Blacktail Creek, on the other hand, is a relatively clean stream and is subject to water quality limitations. Present population growth appears to be in the direction of Blacktail Creek thus, potentially affecting it further. The land use data used are presented in Table 2.

TABLE 2

BUTTE

Drainages 12 & 14-18 discharge to Blacktail Creek.

Drainages 1-11, 13, & 19 discharge to Silver Bow Creek.

	Area	Land Use for Silver Bow Drainage %			
Drainage	Acres	Residential	Commercial	Industrial	Open
1	221	95.9	0.5	0	3.7
2	271	80.7	2.0	9.8	7.5
3	236	65.4	27.4	0	7.2
4	2.4	14.0	33.0	43.4	9.6
5	99	79.1	15.3	0	5.6
6	133	69.4	24.1	0	6.5
7	20	44.0	16.4	0	39.5
8	150	19.1	1.8	62.9	16.2
9	12	88.7	0	0	11.3
10	36	57.5	0	0	42.5
11	73	80.5	12.4	0	7.1
13	44	83.8	11.7	0	4.5
19	991	55.0	5.0	0	40.1
Total	2500	61.0%	10.0%	13%	16%

	Area	Land Use for Blacktail Creek %			
Drainage	Acres	Residential	Commercial	Industrial	Open
12	169	73.3	19.7	0	7.0
14	33	72.0	0	0	28.0
15	85	63.5	0	0	36.5
16	17	18.8	0	0	81.2
17	158	77.8	0	0	22.2
18	45	85.1	4.7	0	10.2
Total	506	72.2%	7.0%	0%	20.8%

Pollutant Loads (lb/year)

	TSS	BOD_5	PO_4	N
Blacktail Creek	77,787	4,674	174	681
Silver Bow Creek	255,353	27,760	3,442	4,216

Present needs include a stormwater collection system in the southwest section of the city and continuation of the discharge pipe to replace surface conduction to creeks. Some additional curb and gutter and catch basins are needed also.

Total suspended solids loading for Blacktail Creek is quite high at 77,787 pounds per year (Table 2); low flow for Blacktail Creek was estimated optimistically at 5 cfs. The water use classification for Blacktail Creek is $B\text{-}D_1$, which limits a turbidity increase to 5 JTU. Using these figures, a dilution time of 4,208 hours or 175 days was found. This compared to a total average number of runoff days in Montana of 21. It is evident that potential for a problem exists in this drainage, particularly, since the city is expanding into the Blacktail Creek Drainage.

A biological assessment of the effect of stormwater discharges on Blacktail Creek is recommended. The assessment should take into account the large increase in stream flow from the golf course to the mouth of the creek. This increase may beneficially dilute stormwaters or it may contain dissolved metals that are more detrimental to biota than stormwater. New subdivisions in the Blacktail Creek Drainage should allow room for a stormwater settling basin or other stormwater pollutant treatment system.

A stream monitoring program should be instituted in addition to the biological assessment. Monitoring parameters should include stream flow, total suspended solids, and turbidity. These data will allow calculation of the suspended solids-turbidity relationship which will indicate the degree of treatment necessary for stormwater runoff from continued growth.

CUT BANK

Cut Bank is located in northcentral Montana on Cut Bank Creek about one quarter of a mile from its confluence with Old Maids Creek. Cut Bank has a mean annual rainfall of 11.53 inches. The community has five drainages; drainage 1 empties into Cut Bank Creek and drainages 2, 3, 4, and 5 enter Old Maids Creek (Figure 4). Cut Bank uses stormsewers, curb and gutter, and overland flow to handle stormwater.

Snow is removed as needed and deposited outside of town in a coulee. Sand is used to control ice. The streets are swept weekly in the commercial area, biweekly in the residential area.

The majority of the stormwater pollutant load is discharged directly to Cut Bank Creek. Since only a small section of Old Maids Creek is affected before discharge to Cut Bank Creek, calculations (Table 3) were made using total flow from both creeks in conjunction with total loadings. This results in an annual TSS load of 98,388 pounds. Land use data along with pollutant loads are shown in Table 3.

The stream impact was calculated using a low flow of 8 cfs. The resulting Minimum Dilution Time is:

$$\text{Time (hours)} = 16,018 \left(\frac{98,388}{3,600(8)30.1}\right)$$

$$= 1,818 \text{ hours or } 76 \text{ days.}$$

Minimum Dilution Time is approximately 3½ times the total available runoff time. Though Cut Bank Creek may obviously receive heavy pollutant loads, the problem is likely not as extensive as the Minimum Dilution Time indicates. However, some further biological study should be initiated to quantify the problem. Any biological assessment

TABLE 3

CUT BANK

Drainage 1 discharges to Cut Bank Creek.

Drainages 2, 3, 4, and 5 discharge to Old Maids Creek and then to Cut Bank Creek.

		Land Use %			
Drainage	Area (acres)	Residential	Commercial	Industrial	Open
1	576	60	22	0	18
2	45.3	39	2	0	58
3	3.2	0	0	0	100
4	3.7	0	0	0	100
5	6.3	0	0	0	100

	Pollutant Loadings (lb/year)			
Drainage	TSS	BOD_5	PO_4	N
1	93,908	7,657	278	933
2-5	4,480	247	9.9	39.8
Total	93,388	7,904	377	973

will almost certainly document biota degradation since stormwater and sewage and water treatment plant wastes are discharged to Cut Bank Creek at essentially the same location. It is recommended that the city consider stormwater and sewage and water treatment plant wastes in its plans for improving waste treatment.

DEER LODGE

Deer Lodge is located in Powell County on the Clark Fork River and at the mouths of Tin Cup Joe and Cottonwood Creeks. The annual average precipitation is 12.20 inches. The city uses storm-sewers and curb and gutter to control stormwater.

There is a snow removal operation for most of the 23.0 miles of streets. Snow is stockpiled in a meadow near Park Street (Figure 5). A good street sweeping program is in effect at the rate of five complete runs weekly. In addition, streets are flushed twice a month.

The city is divided into ten drainages (Figure 5) which discharge to the three streams. Pollutant loads were calculated for all three stormwater discharges; however, since both creeks discharge into the Clark Fork River, the water quality impact was calculated for the combined load to the Clark Fork River. The land use data along with the pollutant loading are presented in Table 4. The annual TSS load, 4,259 pounds, is a relatively small contribution from 4,306 people, and is accounted for by the high factor for street sweeping.

The Minimum Dilution Time for TSS with a low flow of 71 cfs is:

$$\text{Time (hours)} = 16{,}018 \left(\frac{4{,}259}{3{,}600(71)30.1}\right)$$

$$= 8.87 \text{ hours}$$

The large size of the Clark Fork River coupled with the small polllutant load assures that no water quality problems exist from Deer Lodge stormwater.

TABLE 4

DEER LODGE

Drainages 1, 2, 3, 5, 7, and 9 discharge to the Clark Fork River.

Drainage 4 discharges to Tin Cup Joe Creek.

Drainages 6, 8, and 10 discharge to Cottonwood Creek.

LAND USE %

Drainage	Area	Residential	Commercial	Industrial	Open
1	170	33	10	0	58
2	101	32	4	0	64
3	39	74	9	0	17
4	46	71	0	0	29
5	33	49.5	0	0	50.5
6	24	30	0	0	70
7	19	29	58	0	13
8	16	44	56	0	0
9	7	0	0	100	0
10	3	75	25	0	0

POLLUTANT LOADS lbs/year

Drainage	Area	TSS	BOD_5	PO_4	N
1,2,3,5,7,9	368	3,277	230	7.8	31.4
6,8,10	42.8	473	43	1.3	5.0
4	45.5	509	25	1.1	4.2
Total	456	4,259	298	10	41

DILLON

Dillon, in Beaverhead County, is located on Blacktail Deer Creek. There are approximately 443 acres of drainage within the city limits contributing runoff from 11.34 inches of precipitation annually. The city is divided into six drainages which discharge to five channels; only one channel is a perennial stream, Blacktail Deer Creek (Figure 6). The five channels, along with land use of the area drained by each channel, are shown in Table 5. Stormdrains, curb and gutter, overland flow, and open channels control stormwater runoff.

The 19.8 miles of paved streets are cleaned twice a year except for the commercial district, which is cleaned once per week in the summer. There is no snow removal program. The community uses a sand/salt mixture of 12:1 on streets in the business district.

This study considered only the runoff to Blacktail Deer Creek since three discharge channels are drainage ditches and a fourth is the sewage lagoon (Table 5). The stormwater impact could only be measured for Blacktail Deer Creek, a B-D_1 stream, with a turbidity increase limited to 5 JTU.

The calculated annual pound loading of stormwater pollutants from Dillon are presented in Table 5. The Minimum Dilution Time for Blacktail Deer Creek with a low flow of 12 cfs is:

$$\text{Time (hours)} = 16{,}018 \left(\frac{8{,}179}{3{,}600(12)(16.45)}\right)$$

$$= 184 \text{ hours or 8 days.}$$

This minimum time is well below the 500 hours of total runoff expected annually. There should be minimum water quality degradation of Blacktail Deer Creek by stormwater runoff from Dillon.

TABLE 5

DILLON

Drainage	Discharge
1	Owen Ditch
2	Sewage Lagoon
3	Blacktail Deer Creek
4,5	Spruce & Vine Street Ditch
6	Union Ditch

LAND USE %

Drainage	Area (acres)	Residential	Commercial	Industrial	Open
1	222	64.5	16.9	0	18.6
2	19	0	100.0	0	0
3	57	65.0	5.0	0	30.0
4	10	100.0	0	0	0
5	7	100.0	0	0	0
6	30	44.0	8.0	0	48.0

POLLUTANT LOADS lb/year

Drainage	TSS	BOD_5	PO_4	N
3	8179	171	18	71
1	41327	1654	99	385
6	3338	114	9	31
2	4884	704	17	65

GLASGOW

Glasgow is located on the Milk River in Valley County. There are eight drainages, three of which are combined sewers which discharge to a lagoon (Figure 7). One other drainage discharges to the Cherry Creek Overflow, a swampy area having a small discharge to the Milk River. The remaining drainages discharge directly to the Milk River. Drainage 5 consists of the runoff from Highway 2. Stormsewers, combined sewer, curbs and gutter, and surface drainage are used to control stormwater.

There are approximately 17.5 miles of paved and 11.3 miles of gravel streets. The city has a snow removal program and snow is piled in three locations well away from the Milk River (Figure 7). Sand is used on parts of the city with salt added occasionally when necessary.

For the impact analysis, area 3 was neglected due to the nature of the Cherry Creek Overflow in which a great deal of removal of TSS should occur through settling. Drainages 6, 7, and 8 were also omitted since they have combined sewers with rare overflow, only during very large storms. Normally, a combined sewer will overflow directly to the river during rainfall, but the Glasgow system utilizes a high capacity pump to control most flows and discharge them to the lagoon.

Drainage discharge points, land use, and annual pollutant loading are tabulated in Table 6.

The Milk River is classified B-D_3 with a turbidity increase limit of 10 JTU. With a low flow of 13.4 cfs, the Minimum Dilution Time is:

$$\text{Time (hours)} = 16{,}018 \left(\frac{45{,}676}{3{,}600(13.4)30.1}\right)$$

$$= 504 \text{ hours or 21 days.}$$

The quality of the Milk River is fairly poor with high TSS and

TABLE 6

GLASGOW

Drainage	Discharge
1	Milk River
2	Milk River
3	Cherry Creek Overflow
4	Milk River
5	Milk River
6	Sanitary Sewer
7	Sanitary Sewer
8	Sanitary Sewer

LAND USE %

Drainage	Area (acres)	Residential	Commercial	Industrial	Open
1	79	63.0	27.0	0	10.0
2	136	40.0	0	0	60.0
3	281	52.0	6.0	0	42.0
4	153	73.0	0	0	27.0
5	8	0	100	0	0
6	181	43.0	6.0	0	51.0
7	32	100	0	0	0
8	154	31.0	69.0	0	0

POLLUTANT LOADS lb/year

Discharge	TSS	BOD_5	PO_4	N
Milk River	45,676	3,014	106	419
Cherry Creek Overflow	15,733	996	36	143
Combined Sewer (Lagoon)	245,962	24,574	688	2,697

dissolved solids; thus, an increase in the amount of TSS as theoretically calculated does not pose a threat to the river at present. This assumption is further based on a biological study of the Milk River at Havre. The results of that study are presented in the Havre section and indicate no water quality problems due to stormwater discharges. Since water quality is poorer at Glasgow than at Havre and the degradation limits are the same, no problems are anticipated at Glasgow.

GLENDIVE

Glendive is located in Dawson County on the Yellowstone River. Mean annual rainfall is 12.73 inches. The city has six drainages of which four are major contributors to the Yellowstone River (Figure 8). The other two have no formal drainage system. Glendive uses stormsewers with curb and gutter in part of the city with overland flow in the remaining area for stormwater control.

There is a snow removal program with snow piled in vacant areas. Sand is used at the rate of 300-350 cubic yards per season for ice control. The 24 miles of paved streets are swept once per week in the residential area and twice per week in the commerical areas.

The area of drainages 1, 2, 3, and 5 totals 224 acres. The land use data are tabulated in Table 7, along with the resulting pollutant loads to the Yellowstone River at this point.

The Minimum Dilution Time on the Yellowstone, at a low flow of 2,360 cfs and a turbidity increase limit of 10 JTU is:

$$\text{Time (hours)} = 16,018 \left(\frac{15,198}{3,600(2,360)30.1}\right)$$

$$= 0.95 \text{ hours (less than one hour).}$$

This figure, when compared to an average runoff time of 500 hours, is negligible and demonstrates virtually no discernable impact from Glendive stormwaters at this time.

TABLE 7

GLENDIVE

Drainages 1, 2, 3, and 5 discharge to the Yellowstone River

Drainages 4 and 6 slong with fringe areas have no formal drainage pattern.

		LAND USE %			
Drainage	Area (acres)	Residential	Commercial	Industrial	Open
1	89	25.0	75.0	0	0
2	75	70.0	30.0	0	0
3	50	100.0	0	0	0
4	14	95.0	0	0	5.0
5	102	100.0	0	0	0
6	257	90.0	0	0	10.0

POLLUTANT LOADS TO YELLOWSTONE RIVER - lb/yr	
Total Suspended Solids	15,198
BOD_5	1,026
PO_4	35
N	138

GREAT FALLS

Great Falls is the largest community in both size and population of this study. It is located on the confluence of the Sun and Missouri Rivers in Cascade County. The area considered totals 12,139 acres and consists of the city limits plus associated drainages not included within these limits. These outside drainages are directly affected by the population activity associated with the city. The projected 1975 population was 60,868 (as predicted by the Bureau of the Census, "Population Estimates and Projections"). Thus, the difference should be minimal.

The street department maintains a sweeping program with the commercial area receiving two-three passes per week and the remainder approximately six-seven passes per year. Snow is removed when necessary and piled in the city park, baseball fields, and vacant areas. Sand is used in conjunction with calcium chloride in the ratio of:

$$\frac{\text{25-30 tons calcium chloride}}{\text{3,000-5,000 tons sand}} \text{ per average winter.}$$

The area including Great Falls was divided into sixteen separate drainages as shown in Figure 9 and Table 8. These drainages include those to the Sun River and those to the Missouri River. Also, there is one major area in each river drainage which was labeled "Indirect". These areas have no formally defined drainage, but were considered as contributors since they were either surrounded by contributing areas, as in the case of river front land, or affected through population pressure, as in the case of the Great Falls airport. The drainage subtotals are as follows:

TABLE 8

GREAT FALLS

DELINEATION OF DRAINAGES

Drainage	City Limit %	Discharges To:	Area
1	100	Missouri River	2083
2	100	Missouri River	886
3	100	Missouri River	1571
4	100	Missouri River	349
5	100	Missouri River	1815
6	100	Missouri River	488
7	50	Missouri River	812
8	70	Missouri River	499
9	0	Sun River	282
10	0	Sun River	380
11	0	Sun River	231
12	100	Sun River	199
13	100	Missouri River	129
14	0	Missouri River	746
15	100	Sun River (Indirect)	1102
16	100	Missouri River (Indirect)	567

	Missouri (acres)	Sun (acres)
Direct Drainage within City Limits	8,076	199
Direct Drainage outside City Limits	1,302	893
Indirect Drainage	567	1,102

Annual average precipitation for Great Falls is 14.07 inches. The calculated total annual runoff is:

AR = 5.73 - 1.95 = 3.78 inches or 3,823 acre-feet per year.

The developed population density PD_d = 10.91 persons/acre. Land use is shown in Table 9; calculated total annual loads are shown in Table 10.

The impact analysis was done for the combined total TSS to the Missouri River. The 7-day, 10-year low flow used was 3,430 cfs. The water quality limitation for this reach of the Missouri is 10 JTU. The resulting Minimum Dilution Time is:

$$\text{Time (hours)} = 16{,}018 \left(\frac{1{,}786{,}769}{3{,}600(3430)30.1}\right)$$

$$= 77 \text{ hours or } 3.21 \text{ days.}$$

The figure of 77 hours is well within total runoff time available; however, the power dam at Great Falls effectively slows the flow and permits settling out of solids behind the dam. While settling is good for the downstream section, the river by Great Falls may experience considerable long term sedimentation and accompanying stream degradation.

The continued growth potential of Great Falls demands constant attention to planning for stormwater control. All new subdivision and impervious area development should plan for control of stormwater to avoid further aggravation and prevent future problems on this reach of the Missouri River.

TABLE 9

GREAT FALLS

LAND USE - DRAINAGES

Drainage	Area (acres)	Residential	Commercial	Industrial	Open
1	2083	81	4	0	15
2	886	35	55	5	5
3	1571	30	2	0	68
4	349	88	8	0	4
5	1815	40	10	0	50
6	488	85	10	0	5
7	812	50	0	0	50
8	499	66	4	0	30
9	282	55	5	0	40
10	380	0	10	0	90
11	231	40	0	0	60
12	199	70	5	0	25
13	129	70	0	0	30
14	746	20	30	10	40
15	1102	40	10	25	25
16	567	18	18	4	60
Total City Limits		67	11	4	18

TABLE 10

GREAT FALLS

POLLUTANT LOADS lb/year

LOADS TO SUN RIVER

Drainage	Area (Acres)	TSS	BOD_5	PO_4	N
9	282	38,093	2,281	85	338
10	380	13,714	1,790	46	201
11	231	20,455	998	44	176
12	199	33,088	1,916	74	287
15	1,102	242,727	14,326	595	2,325
Total		348,077	122,221	844	3,327

LOADS TO MISSOURI RIVER

Drainage	Area (Acres)	TSS	BOD_5	PO_4	N
1	2,083	387,584	21,455	833	3,270
2	886	156,237	17,126	461	1,807
3	1,571	116,097	7,582	267	1,068
4	349	74,302	4,471	164	646
5	1,815	216,439	15,972	653	2,105
6	488	103,846	6,539	234	917
7	812	88,784	4,336	187	747
8	499	77,285	4,376	170	664
13	129	19,469	953	40	160
14	746	133,881	12,973	380	1,514
16	567	64,768	6,124	181	731
Total		1,438,692	100,910	3,570	13,629
Total Missouri & Sun		1,786,769	223,131	4,414	16,956

HAVRE

Havre is located on the Milk River in Hill County. Havre uses stormsewers and curb and gutters for its stormwater system. There are three main drainages and two discharge points to the Milk River (Figure 10).

The city removes snow only when a traffic hazard exists. Sand is used when necessary in the amount of 500 cubic yards per winter.

The approximately forty-four miles of paved streets are swept approximately once per week. Sweeping, vacuum, and flushing are used.

Annual precipitation is 11.89 inches. The calculated total quantity of runoff is 2.27 inches/year or 433 acre-feet per year. The calculated total pollutant loadings are shown in Table 11. TSS of 113,629 lb/year is compared to a low flow of 15.6 cfs; resulting Minimum Dilution Time is:

$$\text{Time (hours)} = 16{,}018 \left(\frac{113{,}629}{3{,}600(15.6)30.1}\right)$$

$$= 1{,}077 \text{ hours or } 45 \text{ days.}$$

The Minimum Dilution Time is about twice average available and indicates a potential impact on the Milk River from the City of Havre. Havre was one of the first towns for which calculations showed a potential problem. As a result, a biologist was sent to check actual biological stream indicators. A study of benthic invertebrates showed virtually no difference in biological activity between upstream of the stormwater discharge and downstream of the stormwater discharge, which is upstream of the sewage treatment plant. This may be somewhat explained by the normal quality of the Milk River at Havre which is typically high in suspended and dissolved solids. The biota may have become accustomed to the high dissolved and suspended loading to the

Table 11

HAVRE

LAND USE

	%	Area (acres)
Residential	63.3	1444
Commercial	17.3	395
Industrial	0	0
Open	19.4	444
Total Area		2283

Total Pollutant Loading (lbs/year)

Total Suspended Solids	113,629
Biological Oxygen Demand (5 Day)	9,036
Phosphorus (PO_4)	285
Nitrogen (N)	1,117

extent that an additional load would have little effect. Thus, one must conclude that no appreciable degradation of the Milk River by stormwater from Havre exists.

HELENA

Helena is an exception in that it is not located adjacent to a large stream. Prickly Pear Creek, which is perennial, and Ten Mile Creek, which is intermittent, are within one mile of the city limits.

Helena uses stormsewers, curb and gutter, and overland flow to control stormwater. There are four main drainages (Figure 11), all of which discharge to separate sites as shown in Table 12. The annual precipitation is 10.85 inches per year.

Snow is cleared from the 148 miles of paved streets when necessary and hauled out of town where it is landfilled. Streets are treated with sand (3,000 tons) and salt (150 tons).

There is a street sweeping program for most of the city. Broom, vacuum sweeping, and water flushing are employed. The commercial area is swept twice per week and the residential section bi-weekly.

Of the four main drainages, Basin 3 is the only one which discharges to a water course, specifically, Ten Mile Creek. The discharge occurs after slowly passing through a swampy area which provides good treatment for TSS, but allows passage of some nutrients and dissolved BOD. Drainages 1, 2, and 4 end in percolation areas with no normal outlet to water courses. Drainage 2 runoff is treated by three holding ponds; the water is eventually used for irrigation. Land use is listed in Table 12.

The theoretical total runoff for Helena is 2.13 inches/year or 16,721 acre-feet per year.

Calculation for pollutant contributions were done for all four drainages (Table 12). The usual stream impact analysis was not cal-

TABLE 12

HELENA

LAND USE %

Drainage	Area (acres)	Residential	Commercial	Industrial	Open
1	1466	35	4.7	0.3	60
2	1853	53	6	1	40
3	905	34	5	1	60
4	350	51	15	5	30
Total	7,850	34	3	0.5	62.5

DRAINAGE DISCHARGE POINT

1 Percolation to Groundwater

2 Stored with Percolation to Groundwater

3 Good solids settling between Brady Street and Custer, then discharged to Ten Mile Creek

4 Ponds in Agricultural area with Percolation and Evaporation

HELENA

TOTAL ANNUAL POLLUTANT LOADS

Drainage	TSS	BOD_5	PO_4	N
1	80,100	4,056	201	938
2	134,131	6,871	311	1,343
3	50,060	2,534	126	587
4	27,605	1,540	65	272

culated for Ten Mile Creek since pollutant settling occurs before discharge and Ten Mile Creek is intermittent.

The Basin 3 values for BOD-5 (2,534 lbs/year), phosphorus (162 lbs/year), and nitrogen (587 lbs/year) are useful because a fraction of these probably reach Lake Helena during runoff and contribute to its eutrophication and general degradation. A study of the area contributing stormwater to Lake Helena would provide a basis to plan present and future control of nutrient input to the lake.

Though not presently a problem, neglect of stormwater pollution may eventually cause significant problems for Helena. These pollution problems could occur from discharge of untreated stormwater to small streams as a result of removal of natural treatment systems or from failure to provide stormwater treatment in newly developing areas. For example, the Last Chance Gulch Storm Drain (Basin 1) is presently filtered by gravel for approximately 100 yards at a point north of the Burlington Northern Railroad tracks near the southeast corner of the golf course. Should this gravel filter be disturbed (as it was with the identical situation between the golf course, McHugh's Trailer Court, Custer Avenue, and Cole Avenue in 1977), untreated stormwater might reach the Ten Mile Creek drainage. Stormwater passing through the aforementioned filter eventually seeps into the gravel banks northeast of the corner of Custer and McHugh. It is recommended that this area be maintained for seepage and/or the aforementioned filter further upstream be maintained.

The proposed Euclid Avenue Storm Drain System for the western portion of Helena will probably discharge stormwater into Ten Mile Creek near the Green Meadow Golf Course. This stormwater discharge

will require treatment to avoid degradation of the water quality of Ten Mile Creek. Treatment systems designed by the Montana Highway Department should be adequate for a large range of storm intensities, but without a turbidity-total suspended solids-streamflow relationship for Ten Mile Creek, it is impossible to assess actual removal needs. It is recommended that these data be obtained.

LEWISTOWN

Lewistown is located on Big Spring Creek in Fergus County. It has an annual rainfall of 16.52 inches. There are ten major drainages, eight of which contribute to Big Spring Creek (Figure 12). The remaining two discharge to an irrigation ditch. Lewistown utilizes stormsewers and curb and gutter for the majority of its stormwater system.

Snow is hauled and deposited in vacant areas. The city controls ice on the streets using 25 tons of salt per season. All 28 miles of paved streets are swept four times each year, while the commercial area is swept and flushed weekly.

The drainages discharge to five different points, hence, pollutant loads were calculated for common discharge points. The results are tabulated in Table 13.

The total annual runoff as calculated is:

AR = 6.164 - 1.972 = 4.19 inches per year

= 2,920 acre-feet per year.

The Minimum Dilution Time was calculated for Big Spring Creek using a low flow of 97.1 cfs. The result is:

$$\text{Time (hours)} = 16{,}018 \left(\frac{75{,}670}{3{,}600(97.1)30.1}\right)$$

= 115 hours or 5 days.

This time is well below the approximately 500 hours of total annual expected runoff. There should be very little water quality degradation of Big Spring Creek by stormwater runoff from Lewistown.

TABLE 13

LEWISTOWN

DRAINAGE DISCHARGE POINTS

Drainage	Location
2, 3, 9	Discharge directly to Big Spring Creek
1, 6	Discharge to an irrigation ditch
5, 7, 10	Discharge to Little Casino and then to Big Spring Creek
4	Discharges to Boyd Creek and then to Big Spring Creek
8	Discharges to Casino Creek and then to Big Spring Creek

LAND USE %

Drainage	Area (ac)	Residential	Commercial	Industrial	Open
1	168	92	0	0	8
2	220	79	15	0	6
3	59.5	55	30	0	15
4	46	87	13	0	0
5	43	80	0	0	20
6	30	100	0	0	0
7	44	100	0	0	0
8	39	100	0	0	0
9	17.5	100	0	0	0
10	30	100	0	0	0

Total Area 697
Non-Contributing 311

TOTAL ANNUAL POLLUTANT LOADS

Drainage	TSS	BOD_5	PO_4	N
2, 3, 9	55,997	3,379	125	487
1, 6	40,747	1,997	84	329
5, 7, 10	1,458	1,180	50	195
4	9,604	543	21	81
8	8,611	422	18	69

Total TSS to Big Spring Creek = 75,670 lb/year

LIBBY

Libby is located in northwestern Montana in Lincoln County. It is adjacent to the Kootenai River. The town is divided into seven drainages, three of which discharge directly to the Kootenai River (Figure 13). One discharges to Flower Creek, which merges with the Kootenai River at the edge of town. The remaining three are considered non-contributing. Stormsewers are used extensively in Libby, with inlets on almost every corner in the central business district.

Snow is removed from only the main travelled streets and deposited in the old city dump when necessary. Sand is used with as little salt as necessary. The ratio is about 12 pounds of salt per yard of sand. A total of about 400 yards of sand is used per winter. The central areas of town are swept weekly. A broom sweeper followed by water flushing comprises the operation on portions of the 5.3 miles of paved roads.

Pollutant loads were calculated separately for Flower Creek and the Kootenai River. The loadings and land use are tabulated in Table 14.

The total annual runoff as calculated is:

$$AR = 6.81 - 1.98 = 4.83 \text{ inches}$$

$$= 2{,}333 \text{ acre feet per year.}$$

The Minimum Dilution Time was calculated for the total load to the Kootenai River at a low flow of 912 cfs. The results:

$$\text{Time (hours)} = 16{,}018\left(\frac{106{,}968}{3{,}600(912)16.45}\right)$$

$$= 32 \text{ hours or } 1.3 \text{ days.}$$

This amount should not significantly degrade the Kootenai River at the present streamflows, but care should be exercised in future development to plan for stormwater control.

TABLE 14

LIBBY

LAND USE %

Drainage	Basin area	Residential	Commercial	Industrial	Open
1	77.64	87	0	0	13
2	44.04	56	40	0	4
3	265.12	78	5	0	17
4	96.16	81	6	0	13
5	142.41	24	1	0	75
6	16.05	0	15	0	85
7	1.6	0	100	0	0

POLLUTANT LOADS lb/year

Drainage	TSS	BOD_5	PO_4	N
1,2,3	85,614	5,432	194	761
4	21,354	1,271	47	185
Total	106,968	6,703	241	946

LIVINGSTON

Livingston is situated on the Yellowstone River in Park County. It has an annual rainfall of 13.38 inches. There are five major drainages, four of which eventually reach the Yellowstone River (Figure 14). Livingston uses curb and gutter, overland flow, and stormsewers for stormwater control.

The paved streets are cleaned by vacuum sweeping on a regular basis. The residential area is swept weekly, while the commercial areas are swept daily. Snow is removed from the commercial area by loader and stockpiled on city land. Both sand (100 cubic yards) and salt (8 tons) are used in a regular season. There are 35 miles of streets of which 72% are paved.

Drainages 1, 2, and 3 discharge to Sacajawea Lagoon, a branch of the Yellowstone River. The flow to the lagoon can be controlled where it leaves the Yellowstone. Livingston Ditch is an irrigation canal that also receives runoff not returned to the Yellowstone River.

Pollutant loads were calculated for the three Sacajawea Lagoon discharge points. These data, along with land use, are contained in Table 15. The total annual runoff as calculated is:

$$AR = 6.7 - 1.83 = 4.34 \text{ inches}$$

$$= 2{,}617 \text{ acre-feet per year.}$$

The Minimum Dilution Time was calculated for the Yellowstone River and for Sacajawea Lagoon. The low flow used was 590 cfs to give:

$$\text{Time (hours)} = 16{,}018 \left(\frac{109{,}682}{3{,}600(590)16.45}\right)$$

$$= 50 \text{ hours or 2.1 days.}$$

No more records are available for Sacajawea Lagoon, but a good

TABLE 15

LIVINGSTON

Drainage	Basin Area	LAND USE % Residential	Commercial	Industrial	Open
		Sacajawea Lagoon			
1	108	60	40	0	0
2	107	100	0	0	0
3	188	95	5	0	0
Total	403	87	13	0	0
		Yellowstone River			
4	200	5	90	0	5
		Livingston Ditch			
5	370	20	0	0	80

DISCHARGE POINTS

1, 2, 3	to Yellowstone via Sacajawea Lagoon
4	Directly to Yellowstone
5	to Livingston Ditch

POLLUTANT LOADS (lb/year)

Drainage	TSS	BOD_5	PO_4	N
1, 2, 3	30,846	1,581	1,890	251
4	70,991	2,958	172	675
5	7,845	374	19	85

Total TSS to Yellowstone River = 109,682 lb/year

estimate would probably be in the area of 20 cfs. For comparison purposes, this figure is used to find a dilution time. The total annual load of TSS to Sacajawea Lagoon is the sum of Basins 1, 2, and 3, or 30,846 lbs/year. The Minimum Dilution Time is:

$$\text{Time (hours)} = 16{,}018 \left(\frac{30{,}846}{3{,}600(20)16.45}\right)$$

$$= 417 \text{ hours or } 17.4 \text{ days.}$$

This is still a comparatively short time compared to the normal average runoff time of 500 hours and the effect on the Yellowstone River of total TSS load is negligible. Thus, there should be no significant degradation of the Yellowstone from Livingston's stormwater.

Sacajawea Lagoon should be monitored for streamflow, turbidity, and total suspended solids; low flow characteristics are not documented and subsequent stormwater runoff could cause degradation.

MISSOULA

Missoula is located on the Clark Fork River near the confluence with the Bitterroot River. It has an annual rainfall of 12.83 inches. The area immediately surrounding Missoula is quite developed and exerts additional pressure on the Clark Fork and Bitterroot Rivers.

The land area within the city limits totals 3,566 acres. There are eleven different drainages (Figure 15) which collect stormwater from this area. Ten drainages are organized stormsewers (Area 1) which drain the commercial area (280 acres) and discharge to the Clark Fork River. The remaining basin (Area 3) includes a hillside to the south and Pattee Canyon for an area of approximately 10,000 acres. Basin 3 discharges to the Bitterroot River via surface drainage. The undrained area (Area 2 with 2,600 acres) within city limits, uses rock-filled sumps to collect water; disposal is by percolation. This method works well in restricting discharge of pollutants to the rivers.

There are approximately 122 miles of paved streets of which 55% have curb and gutter. Streets are cleaned 3 times per year by flushing, sweeping, and vacuuming. Snow is removed as needed and deposited in areas away from streams. Approximately 750 cubic yards of sand and 250 tons of salt are used seasonally for de-icing.

Pollutant loads were calculated for the Clark Fork River and the Bitterroot River. Land use values and resultant pollutant loads are presented in Table 16. Calculated annual runoff includes the area outside the city limits to the south. This result is:

$$AR = 5.67 - 1,87 = 3.8 \text{ inches per year}$$

$$= 39,195 \text{ acre-feet per year.}$$

Stream impact was calculated for the Clark Fork and the Bitterroot

TABLE 16

MISSOULA

Drainage 1 discharges to the Clark Fork River from the "downtown" area.

Drainage 3 discharges to the Bitterroot River.

LAND USE %

Basin	Area	Residential	Commercial	Industrial	Open
1	280	35	54	0	11
3	10,016	10	0	0	90
Total (area within city limits)	3,566	58	10	2	30

POLLUTANT LOADS lbs/year

Drainage	TSS	BOD_5	PO_4	N
1	64,840	7,279	192	752
3	266,373	12,739	621	2,778
Total to Clark Fork River	331,213	20,018	813	3,530

Rivers separately and for the total of the Clark Fork. All of these show little impact.

Clark Fork before Bitterroot:

$$\text{Time (hours)} = 16{,}018\ \left(\frac{64{,}840}{3{,}600(630)16.45}\right)$$

$$= 28 \text{ hours or } 1.16 \text{ days.}$$

Bitterroot River:

$$\text{Time (hours)} = 16{,}018\ \left(\frac{266{,}373}{3{,}600(547)16.45}\right)$$

$$= 132 \text{ hours or } 5.5 \text{ days.}$$

Total Impact on Clark Fork using 1975 7-day low flow:

$$\text{Time (hours)} = 16{,}018\ \left(\frac{331{,}213}{3{,}600(1483)16.45}\right)$$

$$= 60 \text{ hours or } 2.5 \text{ days.}$$

The last two Minimum Dilution Times were calculated using one-year, 7-day low flow. This is a much higher figure than is obtained using 15 years of data, but the results show such a small impact that only a very great reduction in stream flow would give Minimum Dilution Times approaching the annual average number of runoff hours.

These short dilution times demonstrate the effectivenss of the percolation type of stormwater control. Although overloading of these percolation basins occurs occasionally, the overall benefits seem to be worth the minor inconvenience. Continued use of this method is recommended where substrate is suitable.

A new drainage system for parts of Area 3 is planned. Attention to slowing down of the stormwater may be necessary to protect all residential construction lying in the path of natural drainage. This may allow additional percolation to occur and provide double benefits.

A sampling program for the Bitterroot River at the discharge point of the new planned drainage for Area 3 is recommended. These

data can be used to develop a turbidity-suspended solids-streamflow relationship and facilitate determination of the degree of treatment needed to control future stormwater runoff.

SHELBY

Shelby is a town of 3,111 population located in Toole County near the Marias River. The developed population density, PD_d equals 8.61 persons per acre which is less concentrated than the average density of the larger towns.

The town was divided into five drainages (Figure 16). Drainage 1 is to ponds and is assumed to have no contribution to surface waters. Drainages 2-5 discharge to a ditch which eventually reaches the Marias River.

There are 19.6 miles of improved streets of which 80% are paved. There are some stormsewers, but the majority of stormwater collection is handled by curb and gutter and overland flow to central areas where it is channeled for disposal.

Main street is swept weekly during summer months with the remaining area swept twice a year. Snow is collected regularly in the business area and as needed in the rest of the city. Icy streets are treated with crushed gravel as necessary.

The pollutant load was calculated for drainages 2-5 only. These figures, together with land use values, are tabulated in Table 17. The annual runoff is 4.36 - 1.95 = 2.41 inches = 1,354 acre-feet per year.

The Minimum Dilution Time was calculated for the Marias River assuming all of the pollutant load from 2-5 was discharged directly. This resulted as follows:

$$\text{Time (hours)} = 16{,}018 \left(\frac{67{,}258}{3{,}600(64)16.45}\right)$$
$$= 284 \text{ hours or } 12 \text{ days.}$$

Since this is about one-half of the available runoff hours no potential problem from stormwater degradation is present.

TABLE 17

SHELBY

Drainage 1 - Water ponds in southeast corner of area, no discharge.

Drainages 2 - 5 discharge to a ditch which empties into the Marias River

LAND USE %

Drainage	Area	Residential	Commercial	Industrial	Open
1	80	75	0	0	25
2	62	50	2	0	48
3	110	65	15	0	20
4	240	80	10	0	10
5	70	10	90	0	0
Total 2-5	482	63	22	0	15

POLLUTANT LOADS (lb/year)

Drainage	TSS	BOD_5	PO_4	N
2 - 5	67,258	5,102	165	646

SIDNEY

Sidney is in Richland County near the point where the Yellowstone River flows into North Dakota. It has an annual rainfall of 13.41 inches. The topography is relatively flat with an average distance of 1.5 miles to the Yellowstone River.

The community is divided into seven different drainages (Figure 17). Five drainages eventually reach the Yellowstone River; the remaining two (6 and 7) may flood into Lone Tree Creek during very heavy rainfall, and are considered to discharge to the Yellowstone River also. Total drainage area is 745 acres.

There are about 38 miles of paved streets. A street sweeping program covers the downtown area twice a week and the residential area once every three weeks. Snow is removed as necessary. Streets receive 400 tons of sand and 150 tons of salt per season.

The pollutant load was calculated using all drainages (Table 18). The total annual runoff is:

$$AR = 5.051 - 1.964 = 3.0764 \text{ inches}$$

$$= 2,300 \text{ acre-feet per year.}$$

The stream impact was calculated using an instantaneous low flow of 2,360 cfs. This becomes:

$$\text{Time (hours)} = 16,018 \left(\frac{102,839}{3,600(2360)30.1}\right)$$

$$= 7 \text{ hours or } 0.3 \text{ days.}$$

No real impact on the Yellowstone River occurs according to this short dilution time.

TABLE 18

SIDNEY

Assume all Drainages, 1-7, are direct discharges to the Yellowstone River.

ACTUAL DISCHARGES

1 2 miles to Yellowstone via Lone Tree Creek

2 Discharges to Factory Slough

3 3 miles to Yellowstone via ditch

4 4 miles to Yellowstone via ditch

5 2 miles to Yellowstone via ditch

6 Discharges to field

7 Overland flow to Lone Tree Creek

LAND USE %

Drainage	Area	Residential	Commercial	Industrial	Open
1-5	745	72	13	0	15
6	67	35	25	0	40
7	37	45	0	0	55

SMALL TOWNS

BONNER

Land use is 100% residential, excluding the wood products mill. Highway 200 has many curb inlets that collect runoff into percolation wells. This highway is paved and guttered through Bonner.

Stormwater not picked up by the highway flows northwest from 200 overland and southeast to the railroad tracks. The slope is fairly flat so that most water will pond and percolate or evaporate.

Missoula County is responsible for street maintenance. Streets are broom swept only when requested. Snow is graded to the side unless removal is absolutely necessary. Small quantities of sand are used as needed, primarily at intersections.

For further information, contact Julie Lacasse at 543-7193 for street maintenance and Ralph Heinert or John Price at 258-6161 for stormwater information.

CASCADE

The land use is 15 percent commercial and 85 percent residential. About 25 percent of the community is paved. About 40 percent of the stormwater runoff from Cascade is collected by a storm drain system which discharges to the Missouri River. The remainder is collected in the combined sewer system and conveyed to the sewage treatment lagoon.

Cascade has no street sweeping program. Snow is plowed as necessary; sand and salt are not used. For further information, contact Gary Sanderson in Cascade.

CIRCLE

Circle is located adjacent to Horse Creek into which the three stormsewer systems discharge. Dependent on storm intensity, remaining areas drain overland. Streets are swept occasionally with a broom sweeper. Snow is picked up as necessary and disposed of in a waste area. Sand is used and occasionally salt is added although most temperatures are not suited to salt use. For further information contact R. Hamman at 485-2524.

CORVALLIS

The land use is 90% residential or open and 10% commercial. Stormwater runoff is accomplished mainly through overland flow. The terrain slopes northwest and northeast away from College Street. Runoff to the east is eventually collected by an irrigation ditch. Ravalli County is responsible for snow removal. The streets are plowed and sand is applied as necessary. Contact the Ravalli County Road Crew for further information.

DARBY

The land use is 15% commercial and 85% residential or open. Highway 93 is paved and guttered. Darby has two storm drain systems. One drainage follows Southwic Avenue from James Street to the Burlington Northern tracks where is ends in a swampy area. The other drain system is located on Miles Avenue between James Street and Water Street where it joins an irrigation ditch. These stormsewers drain the central portion of the community as shown on the accompanying map. The town is responsible for street maintenance. Main Street is broom swept weekly. Snow is plowed as necessary; sand is used at intersections as needed. For further information, call Bill Helms at 821-3657.

DUPUYER

Land use is 60% residential, 20% commercial, and 20% open. Areas to the southwest drain through Dupuyer and continue to the northeast, the same direction that Dupuyer Creek flows. There are drain ditches and culverts across a few roads and Dupuyer Creek picks up some of the runoff. Pondera County is responsible for street maintenance. Snow is plowed as necessary.

DUTTON

The land use is 57% residential, 17% commercial, and 26% open. Dutton is drained by overland runoff which is divided by Main Street into north and south flow. A low area in the west part of town collects some water. There are few culverts and no organized drainage ditches. Teton County is responsible for street maintenance which is restricted to only necessary snow plowing and occasional sand application. Contact Teton County for further information.

FAIRVIEW

Fairview uses ditches to control stormwater runoff. Water flows in an easterly direction into two drainage ditches. The city is responsible for street maintenance. Sweeping is on an unscheduled, occasional basis. Snow is hauled out of town. Sand mixed with salt is used to control ice. For further information, contact Ken Sharbono at 747-5616.

GARRISON

Garrison is located between a hillside and the Clark Fork River. Land use is 40% commercial and 60% residential. Groundwater level seems to vary with the height of the Clark Fork River and on occasion is high. In general, water flows west through a swampy area to a bigger swampy area where the tracks turn northwest. No water leaves this area by surface means. The Northern Pacific railroad tracks cut off all surface drainage to the river. The Powell County Road Maintenance Division is responsible for Garrison's minimal street maintenance program. No sweeping is performed since the roads are mostly gravel. Snow is removed only if absolutely necessary.

GEYSER

Land use is 70% residential, 10% commercial, and 20% open. Stormwater runoff is restricted overland flow to the Burlington Northern railroad tracks north of town where a culvert channels water across the tracks to continue overland flow. Some runoff also travels west along the tracks. No culverts are present in town. Judith Basin County is responsible for street maintenance which includes only necessary snow removal and occasional sanding.

HAMILTON

The central section of town including Main Street and part of State Street has a stormsewer system channeling runoff into the Bitterroot River. Overland flow carries water northwest of Main Street and southwest of State Street. Several percolation wells also dispose of stormwater. The Main Street stormsewer past 7th Street West is badly designed; the center of the street is lower than the inlets on the side. The stormsewer always has a flow due to infiltration. Streets are cleaned by the city twice a month or as needed in local areas. Snow is plowed and removed from the downtown area. Sand is used in the commercial areas in the amount of 40-50 cubic yards per season. For further information, call Grant Forsythe or Leroy Stroud at 365-4180.

LOLO

Land use of Lolo is 95% residential and 5% commercial. Lolo has experienced growth of subdivisions with varied drainage patterns. Most stormwater drains via gullies and ditches towards the Bitterroot River; part of the Greenwood Addition drains to Hayden Lake. Numerous curb inlets exist along the highway and collect highway runoff into percolation wells. Highway 92 is paved and guttered. Missoula County is responsible for street maintenance. Streets are cleaned, as required or upon request, from residents by broom sweeping. Snow is plowed and removed if required. Less than 20 cubic yards of sand and gravel mix is used. For further information, contact David Haverfield at 273-2733.

MILLTOWN

Land use is 90% residential or open and 10% commercial. This community controls runoff with overland flow west to the adjacent Blackfoot River. Highway 90 has numerous cord inlets which discharge into dry wells for disposal. Highway 200 is paved and guttered. Missoula County is responsible for street maintenance. Streets are cleaned as requested. Snow is plowed and removed if absolutely necessary. Sand is occasionally used. For further information, contact Ralph Heinert at 258-6161.

MOORE

Moore has two main drainage ditches that flow northwest and join a gravel pit from which a drainage ditch carries runoff to Ross Fork, two miles away. A system of culverts channel these two drainages. The north portion of town drains northeast along the railroad tracks. The runoff is not controlled satisfactorily and many sanitary disposal problems arise; the runoff system needs upgrading. Snow is plowed as necessary. No sweeping facilities exist. For further information, contact Ray Robinson (Mayor) at 374-2341.

OPPORTUNITY

Opportunity land use is about 50% residential and 50% open. The area has high groundwater, a large number of irrigation ditches, and is relatively flat. There are creeks to the north, east, and south of town. Most water will pond, but excess would flow overland to the creek to the east. Some stormwater ditches exist. The county and state share snow removal responsibilities in Opportunity. The main road is plowed and the county participates mostly with sanding of streets. No street sweeping program exists as many streets are dirt or gravel.

ROY

Roy has a ditch system to control runoff. Water from southwest areas drains through town via two main ditches which join and continue to Box Elder Creek. These ditches collect most of the community's runoff and help alleviate the high water problem in Roy. The county is responsible for street maintenance which is restricted to snow plowing as needed.

SAND COULEE

Runoff from a northeast hill and town combines and follows streets to a point west of town and then discharges to Sand Coulee Creek via a drainage ditch. The two main streets are paved. The land use is 85% residential and 15% commercial. Cascade County is responsible for street maintenance. Snow is plowed as necessary.

SAVAGE

Runoff drains to the south via overland flow and eventually empties into the Yellowstone River. Richland County is responsible for street maintenance. No schedule is maintained for street sweeping. Snow is plowed when necessary; sand mixed with salt is used when necessary.

STEVENSVILLE

The land generally drains westward. Highway 269 has a few inlets, some of which discharge to a dry well; the rest surface and flow down streets to the west. Some overland flow is picked up by irrigation ditches; there are no culverts. The main street is broom swept weekly. Snow is loaded and dumped out of town. Sand and gravel is used as needed. For further information, contact Ray Meadows in Stevensville.

STOCKETT

Much of the west hillside drains through Stockett. All of the runoff enters Cottonwood Creek via ditches. Land use is 80% residential and 20% commercial. Cascade County is responsible for street maintenance. Snow is removed from streets as necessary.

SUN RIVER

Stormwater runoff is discharged to the Sun River via ditches; there are no culverts. There is some overland flow. The land use is 54% residential, 33% open, and 13% commercial. Cascade County is responsible for street maintenance. About 25% of the roads are paved, but no street sweeping program is in effect. Snow is plowed as necessary by the county.

VICTOR

Land use is 80% residential and 20% commercial. Runoff drains by overland flow to the northeast and should intercept Sweathouse Creek along Highway 93. The topography is flat and water will pond. Victor has no street sweeping or snow removal programs. For further information, contact Bill Thrailkill at 642-3475.

WOLF CREEK

Wolf Creek is adjacent to Highway 15 and consists of about 60% residential and 40% commercial land use. The area is flat with no real drainage. Any runoff produced on the south side is prevented by the railroad tracks from entering Little Prickly Pear Creek. The soil is porous with little impervious cover. The county plows the road for snow as necessary. Sand accompanies this when ice is present. No sweeping program is in effect.

INDUSTRIES

ANACONDA COMPANY (Anaconda)

The Anaconda Company at Anaconda operates a copper smelter on about 500 acres. The plant site occupies approximately 300 acres. Though the remaining 200 acres has poor vegetative cover as a result of smelter air pollution emissions, newer air regulations have reduced pollutants so vegetative cover can exist and making reclamation possible. Eventually, surface runoff should be curtailed somewhat with the continuing program of providing vegetative cover.

Total pollutant loads generated are:

Area	TSS	BOD-5	PO_4	N
500	174,107	13,270	480	1,881

Resulting runoff is collected and channeled to the treatment lagoon before discharge to the Clark Fork River; this eliminates the need for a stream impact evaluation. Land use values used were 40% commercial and 10% industrial.

ANACONDA COMPANY (Great Falls)

The Anaconda Company is located across the Missouri River from Great Falls on 512 acres. There are 8,000 feet of river frontage. The copper refinery uses approximately 200-250 acres. A nine-hole golf course and company housing area occupy the western portion. An old zinc plant occupied the eastern area which is in the process of being planted with native grasses and trees. The present land use is:

Total Area	Residential	Commercial	Industrial	Open
512	1.4%	0%	43.9%	54.7%

There are eight major drainages of which four directly drain industrial areas. The annual runoff model is not designed to compute flows for industrial areas since population density is not related to imperviousness. Pollutant loads for a pure industrial area are useful and were calculated on a total annual load basis as shown below:

Area (acres)	TSS (lbs/year)	BOD-5 (lbs/year)	PO_4 (lbs/year)	N (lbs/year)
512	94,728	3,949	231	920

The Minimum Dilution Time is:

$$\text{Time (hours)} = 16{,}018 \left(\frac{94{,}728}{3{,}600(3430)30.1}\right)$$

$$= 4.08 \text{ hours.}$$

Total impact on the Missouri River from the Anaconda Company and Great Falls is shown below:

$$\text{Time (hours)} = 16{,}018 \left(\frac{94{,}728 + 1{,}786{,}769}{3{,}600(3430)30.1}\right)$$

$$= 81.09 \text{ hours or } 3.38 \text{ days.}$$

This value is still quite small compared to total runoff time avail-

able of 500 hours. Continued work on revegetation of open areas along with a continuous program for reduction of surface discharges should keep this Anaconda plant from contributing to stormwater degradation. However, the model does not address such pollutants as the heavy metals associated with a lead and zinc smelter and fails to note special industrial conditions. Therefore, judgement must be used in accepting indicated results.

HOERNER WALDORF (Missoula)

Hoerner Waldorf is a wood products industry which makes paper. The plant site is located on 33 acres. Only about 5% or less of the area is paved. All runoff enters the effluent treatment system or percolates into the ground around the edges of the plant. No pollutant loads were calculated as all water is controlled.

HOLLY SUGAR (Sidney)

Holly Sugar is a seasonal industry which annually processes sugar beets in the fall and winter. The plant area is about 99.5 acres. All contaminated runoff is discharged to the holding pond during operation and flows directly to the Yellowstone River during the off season (58% of the year).

The pollutant load was calculated for the direct discharge period.

Pollutant Loads (lb/year)

Area	TSS	BOD-5	PO_4	N
99.5	22,650	936	55	214

The results show relatively small values for the non-operative phase. Hence, there should be no discernable impact on the Yellowstone River, even considering the added runoff from Sidney.

MALSTROM AIR FORCE BASE

Runoff from Malmstrom Air Force Base has been sampled extensively by the Federal government; however, the monitoring program seems to be rather haphazardly planned in relation to the dollars spent and the importance of this facility. Numerous laboratory reports were supplied by Air Force Base personnel, but sampling locations were unclear or so poorly chosen as to be useless in this study.

Some of the reported values from Malstrom were:

Sulfates	Ammonia Nitrogen	Boron	Malathion	COD
650 mg/L	27 mg/L	1.1 mg/L	1.080 mg/L	600 mg/L

Airports have been shown to have high BOD-5 and other contaminants originating from spills of the working fluids such as antifreeze and hydraulic fluids.

More attention should be given to developing a meaningful sampling program which will contribute useful data for predicting pollutant loads from stormwater runoff. Flow measurements should accompany these samples.

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APPENDICES

SEPARATE STORM SEWER PARAMETERS	COLIFORMS (MPN/100ml)	TOTAL SOLIDS (mg/l)	TOTAL VOLATILE SOLIDS (mg/l)	FIVE-DAY BOD (mg/l)
DETROIT, MICHIGAN (PALMER, 1950)	25,000 to 930,000	310 to 914	136 to 414	96 to 234
DETROIT, MICHIGAN (PALMER, 1963)	2,300 to 430,000			
CINCINNATI, OHIO (WEIBEL, 1964)				2 to 84
ANN ARBOR, MICHIGAN (BURM, 1968)				16 to 62
CINCINNATI, OHIO (EVANS, 1968)	23,900 to 45,000,000			
WASHINGTON, D.C. (DeFILIPPI, 1971)	120,000 to 3,200,000	338 to 14,600	12 to 1,004	3 to 660
DORVAL, QUEBEC (SCHULZ, 1974)				0 to 4,780
MADISON, WISCONSIN (KLUESENER, 1974)				
MADISON, WISCONSIN (COWEN, 1976)				
BILLINGS, MONTANA				24
BOZEMAN, MONTANA				
BUTTE, MONTANA	6 to 54,000			
HELENA, MONTANA				
KALISPELL, MONTANA				

SEPARATE STORM SEWER PARAMETERS	TURBIDITY (JTU)	COLOR (STANDARD UNITS)	pH (STANDARD UNITS)	ALKALINITY (mg/l)
DETROIT, MICHIGAN (PALMER, 1950)				
DETROIT, MICHIGAN (PALMER, 1963)				
CINCINNATI, OHIO (WEIBEL, 1964)	30 to 1,000	10 to 380	5.3 to 8.7	10 to 210
ANN ARBOR, MICHIGAN (BURM, 1968)				
CINCINNATI, OHIO (EVANS, 1968)				
WASHINGTON, D.C. (DeFILIPPI, 1971)			6.0 to 7.2	
DORVAL, QUEBEC (SCHULZ, 1974)				
MADISON, WISCONSIN (KLUESENER, 1974)				
MADISON, WISCONSIN (COWEN, 1976)				
BILLINGS, MONTANA	3,000		6.72	
BOZEMAN, MONTANA				40.0 to 90.5
BUTTE, MONTANA			6.8 to 10.9	
HELENA, MONTANA				
KALISPELL, MONTANA			7.1 to 7.6	44 to 287

SEPARATE STORM SEWER PARAMETERS	Ca HARDNESS as $CaCO_3$ (mg/l)	Mg HARDNESS as $CaCO_2$ (mg/l)	TOTAL HARDNESS as $CaCO_3$ (mg/l)	CHLORIDE (mg/l)
DETROIT, MICHIGAN (PALMER, 1950)				
DETROIT, MICHIGAN (PALMER, 1963)				
CINCINNATI, OHIO (WEIBEL, 1964)	24 to 200	2 to 46	29 to 240	3 to 35
ANN ARBOR, MICHIGAN (BURM, 1968)				
CINCINNATI, OHIO (EVANS, 1968)				
WASHINGTON, D.C. (DeFILIPPI, 1971)				
DORVAL, QUEBEC (SCHULZ, 1974)				
MADISON, WISCONSIN (KLUESENER, 1974)				
MADISON, WISCONSIN (COWEN, 1976)				
BILLINGS, MONTANA				
BOZEMAN, MONTANA				74.52 to 336.8
BUTTE, MONTANA				
HELENA, MONTANA				
KALISPELL, MONTANA				

SEPARATE STORM SEWER PARAMETERS	TOTAL SUSPENDED SOLIDS (mg/l)	COD (mg/l)	NO_2 as N (mg/l)	NO_3 as N (mg/l)
DETROIT, MICHIGAN (PALMER, 1950)				
DETROIT, MICHIGAN (PALMER, 1963)				
CINCINNATI, OHIO (WEIBEL, 1964)	5 to 1,200	20 to 610	0.02 to 0.2	0.1 to 1.5
ANN ARBOR, MICHIGAN (BURM, 1968)	470 to 11,900			0.2 to 3.6
CINCINNATI, OHIO (EVANS, 1968)				
WASHINGTON, D.C. (DeFILIPPI, 1971)	130 to 11,280	29 to 1,514		
DORVAL, QUEBEC (SCHULZ, 1974)				
MADISON, WISCONSIN (KLUESENER, 1974)	0 to 777			0 to 1.64
MADISON, WISCONSIN (COWEN, 1976)				
BILLINGS, MONTANA	684 to 1,900	488		
BOZEMAN, MONTANA	601 to 1,656	22.18 to 56.32		0.066 to 0.139
BUTTE, MONTANA				
HELENA, MONTANA	105 to 4,540			
KALISPELL, MONTANA		496 to 1,976		

SEPARATE STORM SEWER PARAMETERS	NH_3 as N (mg/1)	ORGANIC NITROGEN (mg/1)	TOTAL SOLUBLE PO_4 as PO_4 (mg/1)	PHENOLS (mg/1)
DETROIT, MICHIGAN (PALMER, 1950)				
DETROIT, MICHIGAN (PALMER, 1963)				
CINCINNATI, OHIO (WEIBEL, 1964)	0.1 to 1.9	0.2 to 4.8	0.07 to 4.3	
ANN ARBOR, MICHIGAN (BURM, 1968)	0.5 to 2.0	0.3 to 4.0	0.1 to 3.4	1 to 70
CINCINNATI, OHIO (EVANS, 1968)				
WASHINGTON, D.C. (DeFILIPPI, 1971)				
DORVAL, QUEBEC (SCHULZ, 1974)				
MADISON, WISCONSIN (KLUESENER, 1974)	0 to 0.47	0 to 14.0		
MADISON, WISCONSIN (COWEN, 1976)				
BILLINGS, MONTANA	0.66			
BOZEMAN, MONTANA			0.212 to 0.500	
BUTTE, MONTANA				
HELENA, MONTANA				
KALISPELL, MONTANA			900 to 5,400	

SEPARATE STORM SEWER PARAMETERS	SETTLEABLE SOLIDS (mg/1)	VOLATILE SETTLEABLE SOLIDS (mg/1)	VOLATILE SUSPENDED SOLIDS (mg/1)	TOTAL PO_4 (mg/1)
DETROIT, MICHIGAN (PALMER, 1950)				
DETROIT, MICHIGAN (PALMER, 1963)				
CINCINNATI, OHIO (WEIBEL, 1964)			1 to 290	
ANN ARBOR, MICHIGAN (BURM, 1968)	340 to 11,100	2 to 475	31 to 570	1.2 to 16.4
CINCINNATI, OHIO (EVANS, 1968)				
WASHINGTON, D.C. (DeFILIPPI, 1971)	0 to 7,640		0 to 800	
DORVAL, QUEBEC (SCHULZ, 1974)				
MADISON, WISCONSIN (KLUESENER, 1974)				
MADISON, WISCONSIN (COWEN, 1976)				
BILLINGS, MONTANA				
BOZEMAN, MONTANA				
BUTTE, MONTANA				
HELENA, MONTANA				
KALISPELL, MONTANA				

SEPARATE STORM SEWER PARAMETERS	FECAL COLIFORMS (MPN/100 ml)	FECAL STREPTOCOCCUS (MPN/100 ml)	TOTAL NITROGEN (mg/1)	TOTAL PHOSPHATE (mg/1)
DETROIT, MICHIGAN (PALMER, 1950)				
DETROIT, MICHIGAN (PALMER, 1963)				
CINCINNATI, OHIO (WEIBEL, 1964)				
ANN ARBOR, MICHIGAN (BURM, 1968)				
CINCINNATI, OHIO (EVANS, 1968)	1,050 to 1,210,000	5,000 to 290,000		
WASHINGTON, D.C. (DeFILIPPI, 1971)	40,000 to 1,300,000	3,000 to 60,000	0.5 to 6.5	0.2 to 4.5
DORVAL, QUEBEC (SCHULZ, 1974)				
MADISON, WISCONSIN (KLUESENER, 1974)				
MADISON, WISCONSIN (COWEN, 1976)				
BILLINGS, MONTANA	3,800 to 510,000			
BOZEMAN, MONTANA	40 to 460	510 to 7,100		
BUTTE, MONTANA	1 to 34			
HELENA, MONTANA				
KALISPELL, MONTANA	60 to 1,700			

SEPARATE STORM SEWER PARAMETERS	TOTAL PHOSPHORUS as P (mg/l)	PHOSPHORUS DRP (mg/l)	PARTICULATE P (mg/l)	TOTAL OIL & GREASE (mg/l)
DETROIT, MICHIGAN (PALMER, 1950)				
DETROIT, MICHIGAN (PALMER, 1963)				
CINCINNATI, OHIO (WEIBEL, 1964)				
ANN ARBOR, MICHIGAN (BURM, 1968)				
CINCINNATI, OHIO (EVANS, 1968)				
WASHINGTON, D.C. (DeFILIPPI, 1971)				
DORVAL, QUEBEC (SCHULZ, 1974)				
MADISON, WISCONSIN (KLUESENER, 1974)	0 to 1.52	0 to 0.40		
MADISON, WISCONSIN (COWEN, 1976)			0.014 to 2.85	
BILLINGS, MONTANA	0.010			7.0 to 18.0
BOZEMAN, MONTANA				25.0 to 74.5
BUTTE, MONTANA				
HELENA, MONTANA				
KALISPELL, MONTANA	0.1 to 0.9			

SEPARATE STORM SEWER PARAMETERS	SPECIFIC CONDUCTANCE (Micro mhos/Cm^2 @ 25° C)	TOTAL ORGANIC CARBON (mg/l)	STANDARD PLATE COUNT @ 35° C (MPN/100 ml)	COPPER, TOTAL (µg/l)
DETROIT, MICHIGAN (PALMER, 1950)				
DETROIT, MICHIGAN (PALMER, 1963)				
CINCINNATI, OHIO (WEIBEL, 1964)				
ANN ARBOR, MICHIGAN (BURM, 1968)				
CINCINNATI, OHIO (EVANS, 1968)				
WASHINGTON, D.C. (DeFILIPPI, 1971)				
DORVAL, QUEBEC (SCHULZ, 1974)				
MADISON, WISCONSIN (KLUESENER, 1974)				
MADISON, WISCONSIN (COWEN, 1976)				
BILLINGS, MONTANA	4,500	11.0		
BOZEMAN, MONTANA			17,000 to 600,000	51 to 121
BUTTE, MONTANA	175 to 2,403			
HELENA, MONTANA				
KALISPELL, MONTANA	670 t0 710,000			

SEPARATE STORM SEWER PARAMETERS	LEAD, TOTAL (µg/l)	MERCURY, TOTAL (µg/l)	TR ARSENIC (µg/l)	TR IRON (mg/l)
DETROIT, MICHIGAN (PALMER, 1950)				
DETROIT, MICHIGAN (PALMER, 1963)				
CINCINNATI, OHIO (WEIBEL, 1964)				
ANN ARBOR, MICHIGAN (BURM, 1968)				
CINCINNATI, OHIO (EVANS, 1968)				
WASHINGTON, D.C. (DeFILIPPI, 1971)				
DORVAL, QUEBEC (SCHULZ, 1974)				
MADISON, WISCONSIN (KLUESENER, 1974)				
MADISON, WISCONSIN (COWEN, 1976)				
BILLINGS, MONTANA				
BOZEMAN, MONTANA	420 to 1,120	<1.0		
BUTTE, MONTANA			5 to 200	0.13 to 17.0
HELENA, MONTANA				
KALISPELL, MONTANA				

SEPARATE STORM SEWER PARAMETERS	TR LEAD (µg/1)	TR MANGANESE (µg/1)	TR COPPER (µg/1)	TR CADMIUM (µg/1)
DETROIT, MICHIGAN (PALMER, 1950)				
DETROIT, MICHIGAN (PALMER, 1963)				
CINCINNATI, OHIO (WEIBEL, 1964)				
ANN ARBOR, MICHIGAN (BURM, 1968)				
CINCINNATI, OHIO (EVANS, 1968)				
WASHINGTON, D.C. (DeFILIPPI, 1971)				
DORVAL, QUEBEC (SCHULZ, 1974)				
MADISON, WISCONSIN (KLUESENER, 1974)				
MADISON, WISCONSIN (COWEN, 1976)				
BILLINGS, MONTANA				
BOZEMAN, MONTANA				
BUTTE, MONTANA	<10 to 920	70 to 4,200	30 to 2,000	<1 to 30
HELENA, MONTANA				
KALISPELL, MONTANA				

SEPARATE STORM SEWER PARAMETERS	ZINC (μg/l)	CHROMIUM (μg/l)		
DETROIT, MICHIGAN (PALMER, 1950)				
DETROIT, MICHIGAN (PALMER, 1963)				
CINCINNATI, OHIO (WEIBEL, 1964)				
ANN ARBOR, MICHIGAN (BURM, 1968)				
CINCINNATI, OHIO (EVANS, 1968)				
WASHINGTON, D.C. (DeFILIPPI, 1971)				
DORVAL, QUEBEC (SCHULZ, 1974)				
MADISON, WISCONSIN (KLUESENER, 1974)				
MADISON, WISCONSIN (COWEN, 1976)				
BILLINGS, MONTANA				
BOZEMAN, MONTANA				
BUTTE, MONTANA	20 to 4,900	<1.0 to <10		
HELENA, MONTANA				
KALISPELL, MONTANA				

APPENDIX B

Name of Town____________________ Person Filing Report _____________

Person and Phone Number to Call for Questions______________________

On the enclosed map please show:

1. Each stormwater discharge pipe or ditch mouth (specify which).
2. Specify whether each discharge is into stream, ditch, open field, sewage treatment plant, stormwater treatment facility, or whatever.
3. The land and streets that drain to this point (outline that area).
4. The general direction of overland flow in as many points as you desire.
5. The percent of each drainage area that is industrial, commercial, residential or open. Take your best estimate.
6. Mark the streets that are paved and guttered.

Copies of this map are available for a nominal cost at the Montana Department of Highways—Helena, Montana 59601

Name of Town____________________ Person Filing Report_______________

Person and Phone Number to Call for Questions ______________________

On the enclosed map please show:

1. The location of the swimming pool(s). (Please include motels and private.)
2. Show where each pool is drained, if not to sanitary sewer, and show where filter backwash drains, if not to sanitary sewer.
3. What quantity discharged to storm sewer when drained? When filters are backwashed?

Copies of this map are available for a nominal cost at the Montana Department of Highways—Helena, Montana 59601

Name of Town ____________________ Person Filing Report ____________________

Person and Phone Number to Call for Questions __________________________

Maintenance: Complete the following only if town has a street cleaning program.

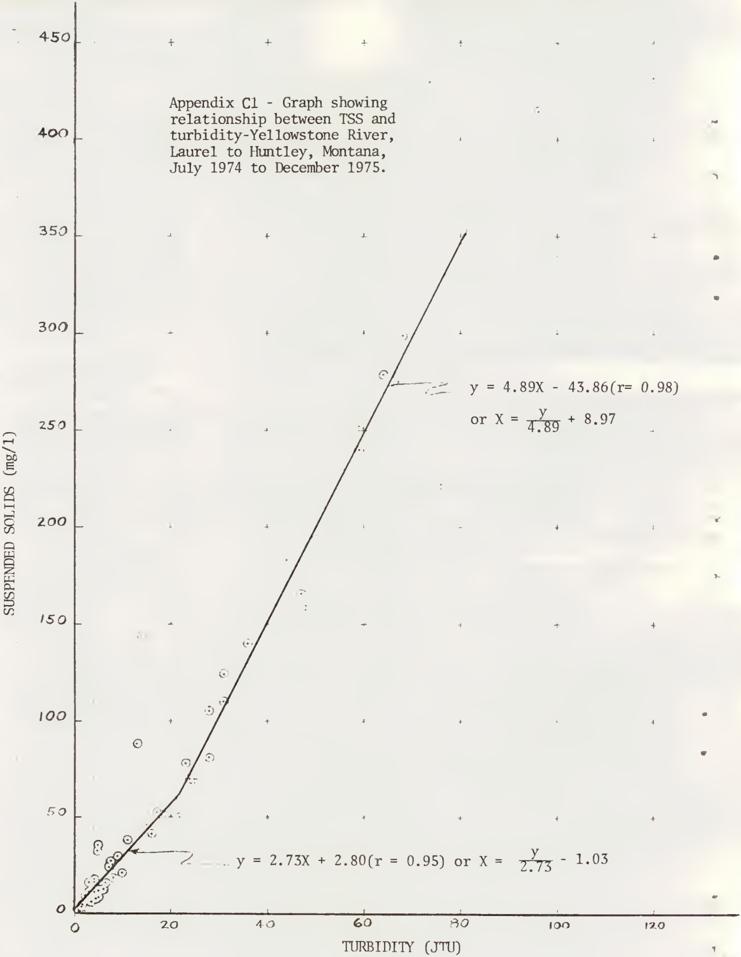
1. Who is responsible for the maintenance of the streets?

2. What is the schedule for street cleaning?

3. How are the streets cleaned (sweeping, vacuum, or flushing)?

4. During winter months, is there a snow removal program for the streets? If so, what are the methods used and ultimate disposal of the removed snow?

5. Does the community use any sanding or de-icing techniques during the winter? If so, what is used (sand, chemicals); and during an average winter, how much is used?



Appendix C1 - Graph showing relationship between TSS and turbidity-Yellowstone River, Laurel to Huntley, Montana, July 1974 to December 1975.

APPENDIX C2

. MATCHED SETS OF DATA FOR FIGURE

Yellowstone River at Laurel (02S24E15CCD)

Date	TSS (mg/1)	Turbidity (JTU)
May 21, 1975	106	28
June 5, 1975	299	68
June 18, 1975	110	31
Aug. 15, 1975	10.1	2.8
Sept. 3, 1975	10.8	4.0
Oct. 2, 1975	5.4	1.8
Oct. 23, 1975	16.4	6.3
Dec. 2, 1975	9.8	2

Yellowstone River at Duck Creek Bridge (02S25E04AAC)

Date	TSS (mg/1)	Turbidity (JTU)
June 5, 1975	279	64
June 18, 1975	144	14
Aug. 15, 1975	12.4	4.0
Sept. 3, 1975	32.3	4.5
Oct. 2, 1975	5.8	3.8
Oct. 23, 1975	29.5	9.0
Dec. 2, 1975	16.0	3.

Yellowstone at Billings South Bridge (01S26E21BB_)

Date	TSS (mg/1)	Turbidity (JTU)
Dec. 11, 1974	4.5	1.5
June 18, 1975	88.8	13.
Aug. 15, 1975	20.2	10.
Sept. 3, 1975	12.2	6.1
Oct. 23, 1975	50.8	18.

Yellowstone at Billings Water Treatment Plant (01S26E02DDB)

Date	TSS (mg/1)	Turbidity (JTU)
July 22, 1974	68	25
July 22, 1974	70	24
July 22, 1974	50	22

Yellowstone at East Bridge (East Bank) (01N26E34AAB)

Date	TSS (mg/l)	Turbidity (JTU)
Aug. 15, 1975	24.0	7
Sept. 3, 1975	11.8	4.8
Oct. 2, 1975	8.5	5.
Oct. 23, 1975	41.1	16.
Dec. 2, 1975	35.1	5.

Yellowstone at East Bridge (West Bank) (01N26E34AAB)

Date	TSS (mg/l)	Turbidity (JTU)
July 1, 1975	240	59
July 3, 1975	415	96
July 7, 1975	432	120
July 11, 1975	252	59
July 14, 1975	194	50
July 16, 1975	166	47
July 18, 1975	140	36
July 21, 1975	124	31
July 29, 1975	78.6	23
Aug. 1, 1975	222	76
Aug. 4, 1975	52	17
Aug. 6, 1975	46.2	15
Aug. 8, 1975	38.5	11
Aug. 13, 1975	27.5	7.7

Yellowstone at Huntley Dam (02N27E34DBD)

Date	TSS (mg/l)	Turbidity (JTU)
Oct. 2, 1975	8.4	4.3
Dec. 2, 1975	16.7	4.0

Yellowstone at Huntley Bridge (02N27E24CBC)

Date	TSS (mg/l)	Turbidity (JTU)
Apr. 25, 1974	81	28
May 21, 1975	158	48
June 18, 1975	183	44
Aug. 15, 1975	18.8	8
Sept. 3, 1975	16.3	4

APPENDIX D

TOWN	STREAM	TURBIDITY LIMIT	LOW FLOW	SOURCE
Anaconda	Warm Springs Creek	(5 JTU)	20 cfs	Low Flow Estimate
Butte	Silver Bow Creek		4 cfs	Low Flow Estimate
Cut Bank	Cut Bank Creek	(10 JTU)	8 cfs	Marias Water Quality Management Plan, 7-day, 10-year low flow
Deer Lodge	Clark Fork River	(10 JTU)	71 cfs	Upper Clark Fork Water Quality Management Plan
Dillon	Blacktail Creek	(5 JTU)	12 cfs	7-day, 10-year low flow, Water Quality Management Plan
Glasgow	Milk River (Nashua)	(10 JTU)	13.4 cfs	7-day, 10-year low flow, Calculation based on 35-year data.
Glendive	Yellowstone River	(10 JTU)	2360 cfs	Instantaneous Minimum flow Lower Yellowstone Basin, Water Quality Management Plan.
Great Falls	Missouri River (Fort Benton)	(10 JTU)	3430 cfs	Missouri-Sun-Smith Water Quality Management Plan, 7-day, 10-year low flow calculation from 15-year data.
Havre	Milk River	(10 JTU)	15.6 cfs	7-day, 10-year low flow, calculation based on 15-year data.
Helena	Ten Mile Creek		0 cfs	Intermittent Stream
Lewistown	Big Spring Creek	(10 JTU)	97.1 cfs	7-year average of instantaneous low flow, 1950-1960 USGS
Libby	Kootenai River	(5 JTU)	912 cfs	Kootenai River 7-day Instantaneous
Livingston	Yellowstone River	(5 JTU)	590 cfs	Upper Yellowstone Water Quality Management Plan, Instantaneous Low Flow
Missoula	Clark Fork River	(5 JTU)	630 cfs	7-day, 10-year low flow, calculation based on 15-year data
Shelby	10 Miles from Marias River	(5 JTU)	64 cfs	7-day, 10-year low flow based on Marias River Basin Study
Sidney	Yellowstone River	(10 JTU)	2360 cfs	Lower Yellowstone River Basin Water Quality Management Plan Minimum Instantaneous Flow